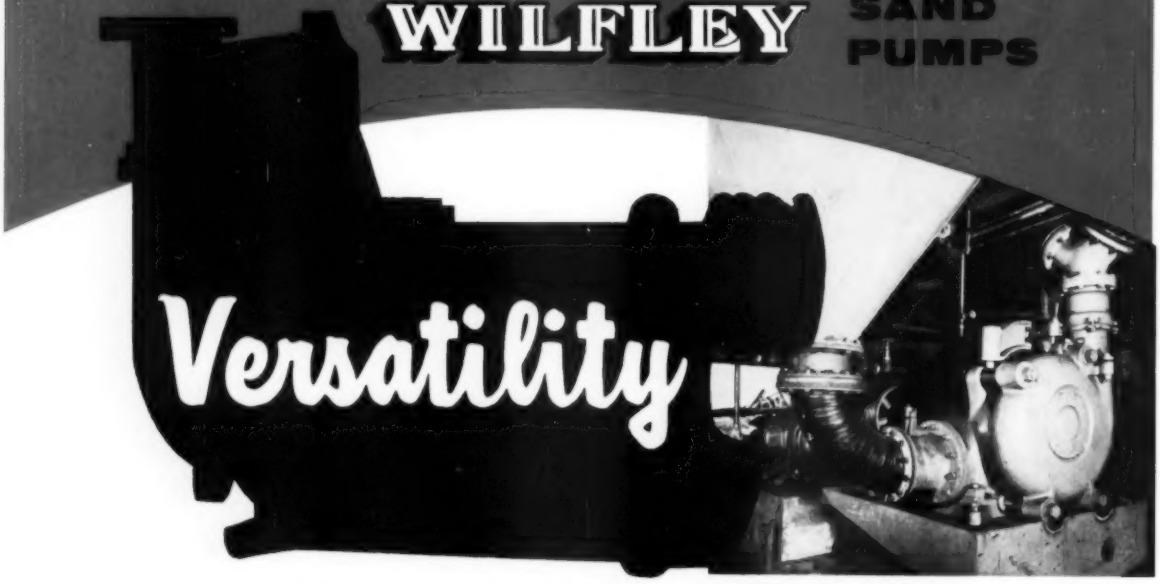
MINING engineering

NOVEMBER 1959

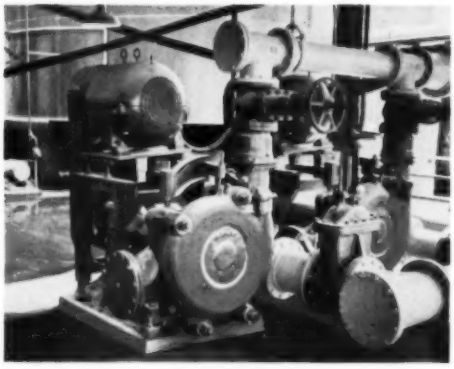
WILFLEY SAND PUMPS



Versatility

to Solve Your SPECIFIC Pumping Problems

Every year the applications for Wilfley Sand Pumps become more varied. So **many** industries now require low cost pumping of sand, slimes, slurries—abrasive solutions of all types. Wilfley Sand Pumps are designed to meet all requirements in the transfer of solids. They may be fitted with interchangeable electric furnace alloy iron, special application alloys, or rubber-covered wear parts. Whether you need belt driven, overhead V-belt driven, or direct driven pumps, Wilfley has them—available in **1"**, **1½"**, **2"**, **2½"**, **3"**, **4"**, **5"**, **6"**, **8"** and **10"** discharge sizes with capacities to 3600 GPM and heads as high as 200'.



This all-around versatility plus continuous, maintenance-free performance and longer pump life make Wilfley the No. 1 choice of economy-minded plant operators throughout the world. To give you maximum economy in solids pumping, every Wilfley installation is **Job Engineered.**

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COMING EVENTS

Nov. 9-12, Society of Exploration Geophysicists, annual meeting, Biltmore Hotel, Los Angeles.

Nov. 19, AIME Utah Section, "Geology of Anaconda's Chuquicamata Mine" by G. C. Waterman, Newhouse Hotel, Salt Lake City.

Nov. 19-20, Missouri School of Mines, 5th Symposium on Mining Research: ammonium nitrate explosives, field performance, safety, Missouri School of Mines, Rolla, Mo.

Nov. 30, American Mining Congress, annual membership meeting, Plaza Hotel, New York.

Dec. 4, AIME Lehigh Valley Section, ladies' night.

Dec. 5, AIME Knoxville Area Subsection, Southeast Section, annual Christmas Party, C'est Bon Restaurant, Knoxville, Tenn.

Dec. 6, 7, AIME Arizona Section, annual meeting, Speaker: J. L. Gillson; Tucson, Ariz.

Dec. 10, AIME Chicago Section, students' night.

Dec. 10, AIME Oregon Section, J. L. Gillson, speaker; Portland, Ore.

Dec. 12, AIME Montana Section, annual meeting, J. L. Gillson, speaker; Butte, Mont.

Dec. 17, AIME Utah Section, "A Geologist's View of the Montana Earthquake," by Dorsey Hager, Newhouse Hotel, Salt Lake City.

Jan. 6, 1960, AIME Chicago Section, "Nitrogen Quench of Experimental Blast Furnace," by J. L. Bosley, Chicago.

Jan. 11, AIME Minnesota Section, annual meeting, J. L. Gillson, speaker; Duluth.

Jan. 21, AIME Utah Section, "Bear Creek Mining Company's East Tintic, Utah, Lead-Zinc Development," by J. B. Bush and D. R. Cook, Newhouse Hotel, Salt Lake City.

Feb. 14-18, AIME Annual Meeting, Hotels Statler and Sheraton-Atlantic, New York.

Feb. 16-17, 10th annual California Statewide meeting, Governor's Industrial Safety Conference, Fairmont Hotel, San Francisco.

Feb. 16-19, Australasian Inst. of Mining and Metallurgy, Symposium on Hydrometallurgy, "Wet Processing of Minerals and Industrial Products," Adelaide, Australia.

Apr. 4-6, AIME National Open Hearth and Blast Furnace, Coke Oven, and Raw Materials Conferences, Palmer House, Chicago.

Apr. 6-9, International Mineral Processing Congress, sponsored by The Institution of Mining and Metallurgy, Church House, Westminster, London, England.

Apr. 21-22, AIME Pacific Southwest Regional Metals and Minerals Conference, Ambassador Hotel, Los Angeles.

Apr. 28-30, AIME Pacific Northwest Regional Conference, Sheraton Hotel, Portland, Ore.

May 9-11, American Mining Congress, Coal Convention, Pittsburgh.

May 16-20, International Conference on Strata Control, sponsored by Charbonnages de France, Paris, France

July 11-18, 2nd World Conference on Earthquake Engineering, organized by Science Council of Japan in cooperation with Japan Soc. of Civil Engineers, Architectural Inst. of Japan, Seismological Soc. of Japan; Tokyo and Kyoto, Japan.

Aug. 15-25, International Geological Congress, Copenhagen, Denmark; for information, write Mineralogical-Geological Museum, University of Copenhagen, Oster Voldgade 7, Copenhagen K, Denmark.

Oct. 5-7, AIME Rocky Mountain Minerals Conference, Utah Section host, Newhouse Hotel, Salt Lake City.

Oct. 10-13, American Mining Congress, Mining Show (metal mining-industrial minerals convention, exposition), Convention Center, Las Vegas, Nev.

Feb. 19-23, 1961, AIME Annual Meeting, St. Louis.

Sept. 17-20, Commemoration of the 50th Anniversary of Froth Flotation in the U.S.A., sponsored by AIME: Society of Mining Engineers' Mineral Beneficiation Division, Cosmopolitan Hotel, Denver.

MINING engineering

Vol. 11 NO. 11 **NOVEMBER 1959**

COVER *Safety in the mine means dollars in your pocket. An article on page 1116 tells how one big operation revamped its safety program to drive accidents down and profits up. Sir Humphrey Davy's safety lamp—one of mining history's most invaluable devices underground—was chosen by Artist Herb McClure to point up the theme.*

TECHNICAL ARTICLES

1116 **At Braden Copper Co. Safety Means Economy** • *S. M. Jarrett*

1120 **Developing Chuquicamata's Open Pit Haulage System** • *Robert Laurich*

1129 **Mining Laws of Mexico** • *L. G. Gutierrez and A. S. Segura*

1133 **Pebble Milling Practice at the South African Gold Mines of Union Corp. Ltd.** • *O. A. E. Jackson*

1145 **Time Aspects of Geothermometry** • *R. J. P. Lyon*

1151 **Factors Affecting the Cleaning of Fine Coals by the Convertol Process** • *S-C Sun and W. L. McMorris*

PALEY REPORT

1123 **Fluorspar and The Industrial Minerals** • *R. B. Ladoo*

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MINING ENGINEERING staff, Society of Mining Engineers, and AIME Officers are listed on the *Drift* page.

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PERSONNEL

THESE items are listings of the Engineering Societies Personnel Service Inc. This Service, which cooperates with the national societies of Chemical; Civil; Electrical; Mechanical; Mining, Metallurgical, Petroleum Engineers, is available to all engineers, members and nonmembers, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5 pct of the first year's salary of a nonmember, or 4 pct if a member. Also, that you will agree to sign our placement fee agreement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number. When making application for a position, include 8¢ in stamps for forwarding application to the employer and for returning when possible. A weekly bulletin of engineering positions open it available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for nonmembers, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.**

MEN AVAILABLE

Mining Engineer, E.M., degree, age 34. Eight years spent in mining, open pit and underground. Mine layout, shaft design, production and geology. Five years supervisory position. Fluent Spanish and German. Location, Central and South America. M-511.

Geological Engineer, M.S., age 25, single. Three years experience as instrument operator and computor with seismic crew, now desires to become established in mineral exploration field. Thesis experience in photogeology. Foreign positions acceptable. M-512.

Sales, Operations-Mining, Milling, mining engineer, metallurgist, age 45. Extensive experience in field work, laboratory, design; operation of flotation, gravity, and chemical plants; sales engineering and management. $800 up. Prefer West, Foreign. Home, California. S(M)-802

Supervise, Consultant, Instructor—Underground Metal Mining, M.S. in mining, age 61. Continuous service leading underground metal mines as engineer, superintendent, administering large and medium tonnage production with development, exploration and construction. Vice-president and general manager of successful operation for past ten years. Physically capable. Salary open. Prefer U. S. Home, California. S(M)-692.

Mill Foreman, Plant Engineer—Mine, Mill, Industry, E.M. degree, age 46. Two years as mill shaft foreman doing crushing, grinding, classification, flotation, concentration, cyanidation, lead, silver, and zinc ore. Eight months as assistant mine superintendent on development and exploration, underground and surface. Three and one-half years assay, mill, mine shift boss on silver, gold, copper mines. $600. Prefer California; will consider any location. Home, San Francisco. (SM)-463.

Geologist—Base Metals, Uranium, geologist, age 34. Has been a geologist for 4½ years doing reconnaissance, geological mapping, sampling, exploration, and making reports on base metals and uranium properties. For eight years worked part-time as teaching assistant and zoologist for university and oil company. $550 to $600. Prefer Pacific Northwest. Home, California. S(M)-423.

Geologist—Exploration, Production, M.S. degree, age 25. Three months well sample geologist for drilling and oil companies. Three months geologist, structural, stratigraphic and field for the government. Three months field mapping, well-logging, surveying of copper deposit. Three months construction operator on road building. $450. Prefer Western U. S. Will consider any location. Home, Arizona. S(M)418.

Mine Foreman—Surface, Underground, E.M., age 31. Six years mine foreman, in charge of operations of zinc mine. Two years Army service (completed). $650. Prefer Western U. S. Will consider any location. Home, Colorado. S(M)-416.

Mine Engineer, Metallurgist—Mine, Mill, Manufacturing, Metallurgical Engineer, age 41. Two years consulting mining and metallurgical engineer on non-ferrous minerals, heavy aggregate field, examination, reports, studies. Metallurgist for 4½ years working on construction of plant, ore dressing, operation for uranium, lead, copper smelting. For 2½ years in charge of development of mining beneficiation of phosphate rock, process changes in chemical and reduction plants on titanium. Plant superintendent for 1½ years, doing production, materials handling, equipment of gypsum processing. $10,500. Prefer West, Northwest. Home, Texas. S(M)-207.

Mine Engineer—Mining, Oil: Geologist, age 39. Three years as mill and mine operator, geological consultant on mica and non-metallic ores. Three years geological consultant on evaluation and development of uranium, oil, and mineral properties. One year hydrology, ground water studies for the government. Four years right-of-way, compute, draft for reclamation. $575. Prefer Mexico, Foreign, Western U. S. Home, New Mexico. S(M)-337.

Geologist, Teacher—Mining, M.A. in geology, age 39. One year exploration and mining for mining companies. Lab assistant on asphalt products for 1½ years. Six months as party chief for geological, geochemical, and electromagnetic anomalies. Five months survey, draft for survey bureau. Salary open. Any location. Home, Michigan. S(M)-326.

Geologist—Mining, Petroleum, age 33. Four years in charge of exploration and development, underground and surface, doing mapping, diamond drilling, milling for mining companies. $500. Prefer Mexico or any location. Home, Mexico. S(M)-1438.

Superintendent—Mining, Allied, E.M. age 55. Thirty years experience in planning, supervising production, mine examination, exploration and development programs on mining, petroleum, metallurgy. $700. Prefer U. S. Home, Colorado. S(M)-221.

Junior Engineer, Sales—Mining, Heavy Equipment, E.M., age 24. Nine months as sampler, surveyor, plane table, stake claims, assessment for mining, exploration company. Salary open. Any location. S(M)-197.

OPPORTUNITY FOR

Chemical or Metallurgical ENGINEER

and

Analytical CHEMIST

Must have experience with sampling and process chemistry in the uranium milling field, preferably with some background in radiation protection. Project responsibilities. Travel essential to proper job performance. Applicants must have experience in discharging project responsibilities, independently, without close supervision.

LOCATION: GRAND JUNCTION, COLORADO

With project closely associated with eastern laboratory working on fundamental and applied physical and chemical studies of radioisotopes.

Send detailed resume covering education and general and specific experience to:

Assistant Technical Director
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Grand Junction, Colorado

Ore dressing metallurgist to work on process development and mill control at a progressive mining operation. Liberal housing and employe benefits. Apply for application form to: **Box 9ME, AIME, 29 W. 39th St., New York 18, N. Y.**

Assistant Superintendent in a well-established sulfide flotation plant located in Eastern United States. Should have a degree in metallurgical or chemical engineering, at least ten years experience in sulfide flotation research and operating, and recognized executive ability. Must be able to organize and supervise the development program for improving the process, in addition to the normal duties of an assistant plant superintendent. Submit complete record and expected salary to **Box 10-ME.**

POSITIONS OPEN

Engineers for a mining operation. a) **Mine Foreman,** previous Latin American experience required; ability to speak Spanish. Married man considered. Salary $6000 yearly. b) **Mill Superintendent** with extensive experience in both metallurgy and operation. Most of experience should have been in cyanidation. Good knowledge of Spanish. Salary, $8400 to $9000 yearly. All salaries plus benefits which amount to 2½ months salary a year. Location, South America. F7975.

Sales Engineering Assistant, mechanical graduate, with equipment experience in construction, mining, materials handling or allied fields. Salary open. Headquarters, New York, N. Y. W7965.

Assayer, Metallurgist—Gold, Met., E.M., young. Well experienced in gold cyanide milling, in charge of assay and metallurgical test, to improve mill recovery. 16,000 tons per month gold-quartz ore and amalgamation. Sand and slime cyaniding plus iron and lead flotation. $6000 up. South America. S(P)-4633.

Mineral Process and Quality Control Engineer to supervise quality control and to engineer processes, changes, improvements, and additions in a combined wet and dry non-metallic mineral pigment beneficiation and grinding plant. Will report directly to plant manager. Position will lead to complete mineral processing in a very short time. Salary open, opportunity for advancement. Location, northeastern New York State. W7649.

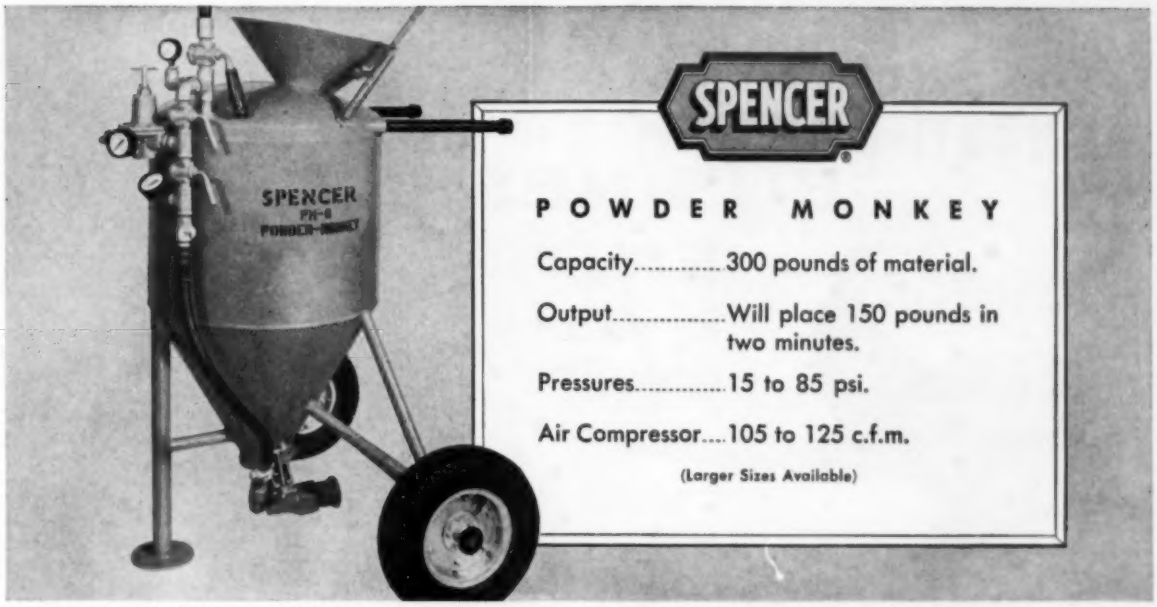
Sales Engineer, young, with experience in gravity separation and flotation equipment, capable of laying out flowsheets and plant design and familiar with testing procedures, evaluations and initial start-ups. Salary open. Location, eastern U. S. W7665.

a) **Design Engineers—Industrial**—Mining, C.E. or Mechanical Engineering degree preferred, with previous industrial design experience in connection with mining, ore dressing, and smelting or refining plants, equipment, and facilities. $600 to $800. b) **Construction Engineer—Smelting Plant,** C.E. or M.E., with previous experience in directing or coordinating plant construction work, preferably in connection with non-ferrous smelting plants. $600 to $850. c) **Estimator,** Mining Engineer, Metallurgical Engineer, or ME; broad experience in heavy industrial construction and engineering estimates, preferably mining and mineral industries. Qualified to make cost estimates on projects budgetary and appropriation estimates, supervise small group. Salary and benefits. Western U. S. S (P)-4627.

Mining Engineer—Cinnabar, E.M., under 50. Experience in underground and possibly some open pit mining process operating retort for mercury extraction. Should be able to open mine operation and carry it through to production and mill operation and installing mill and retort equipment. $800 to $1000 plus bonus. High Sierras. S(P)-4611.

Consultant Metallurgist—Copper, under 50. Wide metallurgical experience in copper, smelting, and refining; familiar with opera-

(Continued on page 1076)



One man is all it takes to fill horizontal holes with Spencer N-IV Ammonium Nitrate and fuel oil, when you use the new Spencer Powder Monkey. Available with wheels for towing, or mount on powder truck.

Now! A Fast, Easy Way To Fill Horizontal Holes With Ammonium Nitrate-Fuel Oil Mixtures:

New Spencer Powder Monkey saves you $3.00 to $4.00 per 100 pounds on bag costs alone!

Scientifically designed for placement of Spencer N-IV Ammonium Nitrate-fuel oil mixtures in horizontal blast holes, the Spencer Powder Monkey extrudes the mixture into the hole. Then the Powder Monkey is filled with sand, which is blown into the holes for stemming.

There's no need for tamping bags, tamping equipment, or the labor needed to fill and tamp bags into the hole!

With the Spencer Powder Monkey, you can actually load faster and more economically than with any other known method! Job-tested on holes ranging from 1⅝ inches to 8 inches in diameter, the Powder Monkey has proved itself under a wide variety of conditions.

Another advantage of placing Spencer N-IV and fuel oil with the Powder Monkey is that you can prime the entire charge with detonating cord at the same time you insert the hose in the blast hole for filling.

World's Most Efficient Low-Cost Blasting Method

Spencer N-IV Ammonium Nitrate, combined with fuel oil and fired with detonating cord, produces a superior blast for these two reasons: (1) Spencer N-IV has a special structure that lets the prills absorb oil more easily. (2) Spencer N-IV contains a higher percentage of ammonium nitrate than other brands.

Because of these two advantages, Spencer N-IV as an ingredient in blasting agents produces more energy than competitive grades of ammonium nitrate, yet costs no more!

With Spencer N-IV and fuel oil you save on priming costs, too, because this mixture can be initiated with a single strand of 175-grain detonating cord. And you put an end to the danger of storing high explosives on the job site because Spencer N-IV by itself is not an explosive!

Spencer N-IV is available in all-plastic 50-lb. bags that are tougher than paper—so tough they reduce breakage as much as 50%. And you can store them right out in the open. (Also available in paper bags.)

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choose it carefully!

The BUCKET can make the difference in profits you earn on a major investment — your dragline! Take a look at the extras built into every Bucyrus-Erie dragline bucket:

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LETTERS

Gentlemen:

In the August issue of MINING ENGINEERING, on page 787, you have some very amazing facts about New York City, supposedly taken from the New York Subway System Reader. I don't agree with your figures. Your article says that there are over 300 million pounds of copper beneath New York City pavements. That could be true. Next you say that if this were contained in 1 pct ore it would be a 150 million-ton orebody. I think you will find this should be 15 million tons. At 50,000 tpd it would take one year not 150 years to mine. That is on a 300 day per year basis. Even 150 million tons at 50,000 tpd would only take ten years to mine.

It looks like the New York Subway System Reader should stick to facts about the subways.

Yours very truly,
Frank J. Traversone
The Anaconda Co.

Ed. Note: The Subway Reader was correct. This was only one of the letters we received. It wasn't a slide rule error but our misplaced decimal point that gave New York's copper deposit such a long life.

$$\frac{300 \times 10^6 \text{ lb Copper}}{20 \text{ lb per ton}} = 15 \times 10^6 \text{ tons}$$

not 150×10^6

50×10^3 tpd $\times$ 3×10^2 days $= 15 \times 10^6$ tons per year

Mine life, therefore, is one year, not 150 years.

PERSONNEL

Continued from page 1074

tions and engineering in copper producing areas throughout the world. Provide technical direction for metallurgical plant and design construction, also technical assistance to operate smelters and refineries and handle development work for new methods. Must be top-notch with sound economic sense. Capable of contact work under variety of circumstances including top management. Salary open, commensurate with experience. Headquarters, Mountain States. S(P)-4660.

Field Engineer—Mining Tools: Mining Engineer or other engineering field and two to three years experience in mining or quarrying. Visit mines and quarries and observe tests of company products (rock bits for blast hole drilling, rock cutters for drilling shafts and tunnels), discuss with mine and quarry management problems of drilling, study mechanical and metallurgical aspects of products for drilling, study mechanical and metallurgical aspects of new projects. Short training program provided. For tool manufacturer. Travel extensively. Headquarters, Southwest. S(P)-4658.

Metallurgist—Hydro, E.M. or Met., age open. Primary interest in lab test work to investigate extensive metallurgical problems in flotation and hydro-metallurgy. Knowledge of Spanish. Single preferred, married acceptable. For mining company. $600 plus benefits. South America. S(MP)-4647.

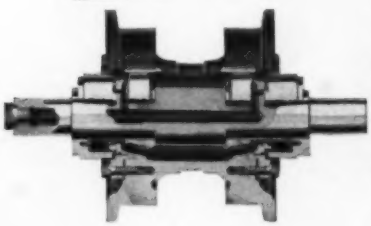
Why waste time greasing track on any of your tractors...

when you can have

Permanent Lubrication CERTIFIED

The Positive Seal AC PERMA-SAFE Wheel

for truck wheels, front idlers and support rollers on all models of Allis-Chalmers crawler tractors



Now... Allis-Chalmers announces PERMA-SAFE lubrication for all models in its crawler tractor line... climaxing more than 20 years of constant research and on-the-job experience with Positive Seal, tapered roller bearing design. Now you can forget about track-level greasing...convert that lost time to profit time. Allis-Chalmers, pioneer of extended lube intervals, lets you take this big step ahead with complete confidence.

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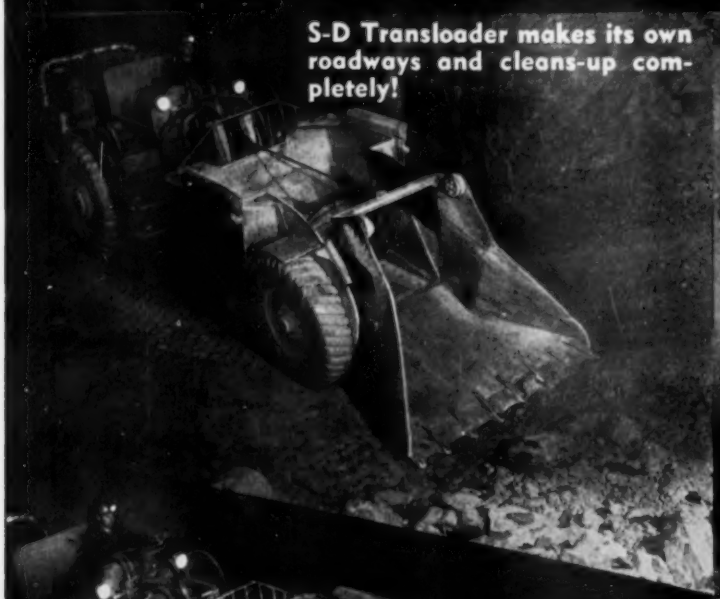
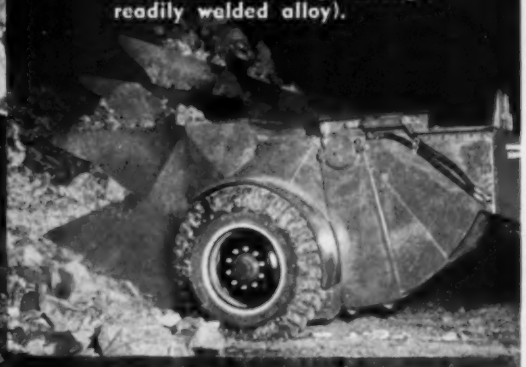


S-D Transloader makes its own roadways and cleans-up completely!

All wearing surfaces feature T-1 Steel (a new high strength readily welded alloy).



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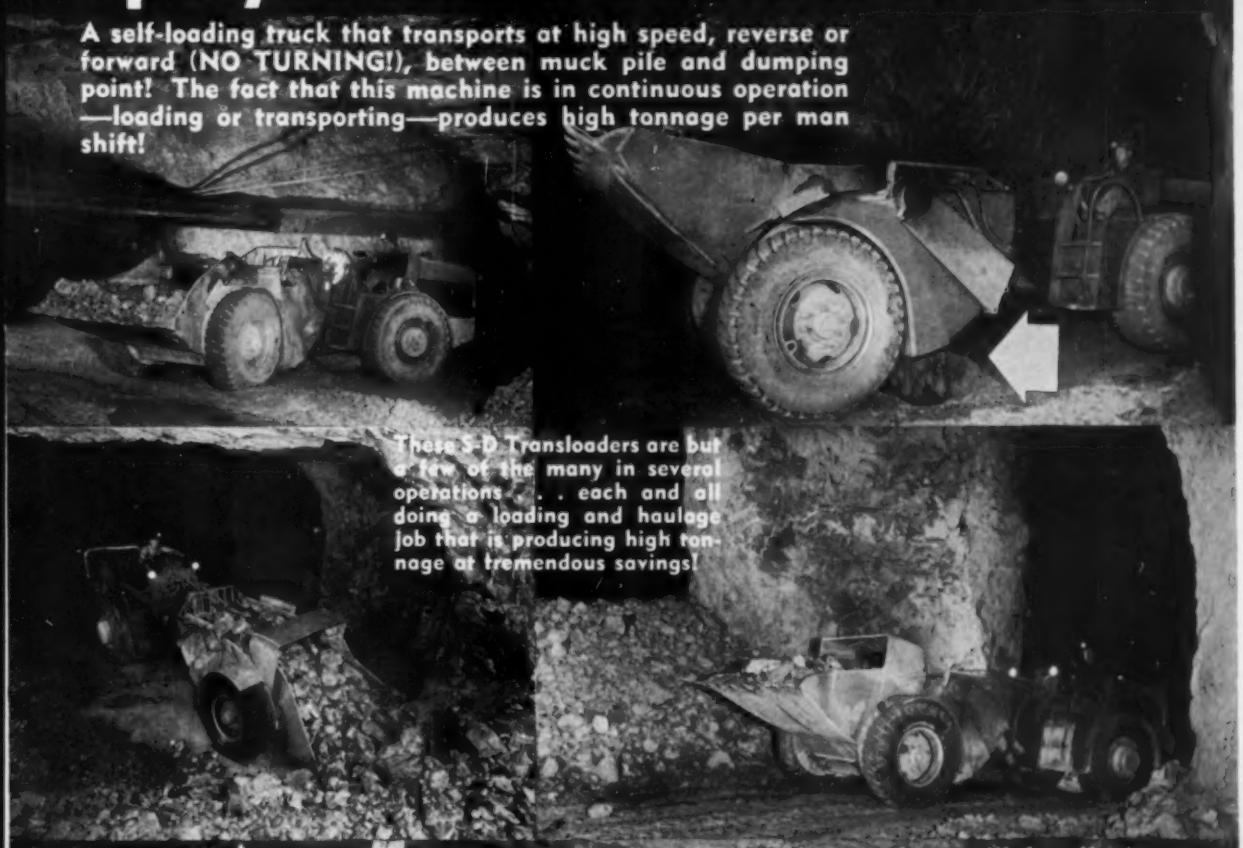
ONLY MACHINE ON THE MARKET THAT SELF-LOADS AND TRANSPORTS!

a job you cannot afford to overlook!

A self-loading truck that transports at high speed, reverse or forward (NO TURNING!), between muck pile and dumping point! The fact that this machine is in continuous operation —loading or transporting—produces high tonnage per man shift!



These S-D Transloaders are but a few of the many in several operations . . . each and all doing a loading and haulage job that is producing high tonnage at tremendous savings!

Investigate the tonnage this machine will handle in your mucking and tramming operation — and the tremendous savings!

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Gentlemen, please forward by return mail complete Information Packet, including time studies, specifications, etc., on the S-D Transloader!

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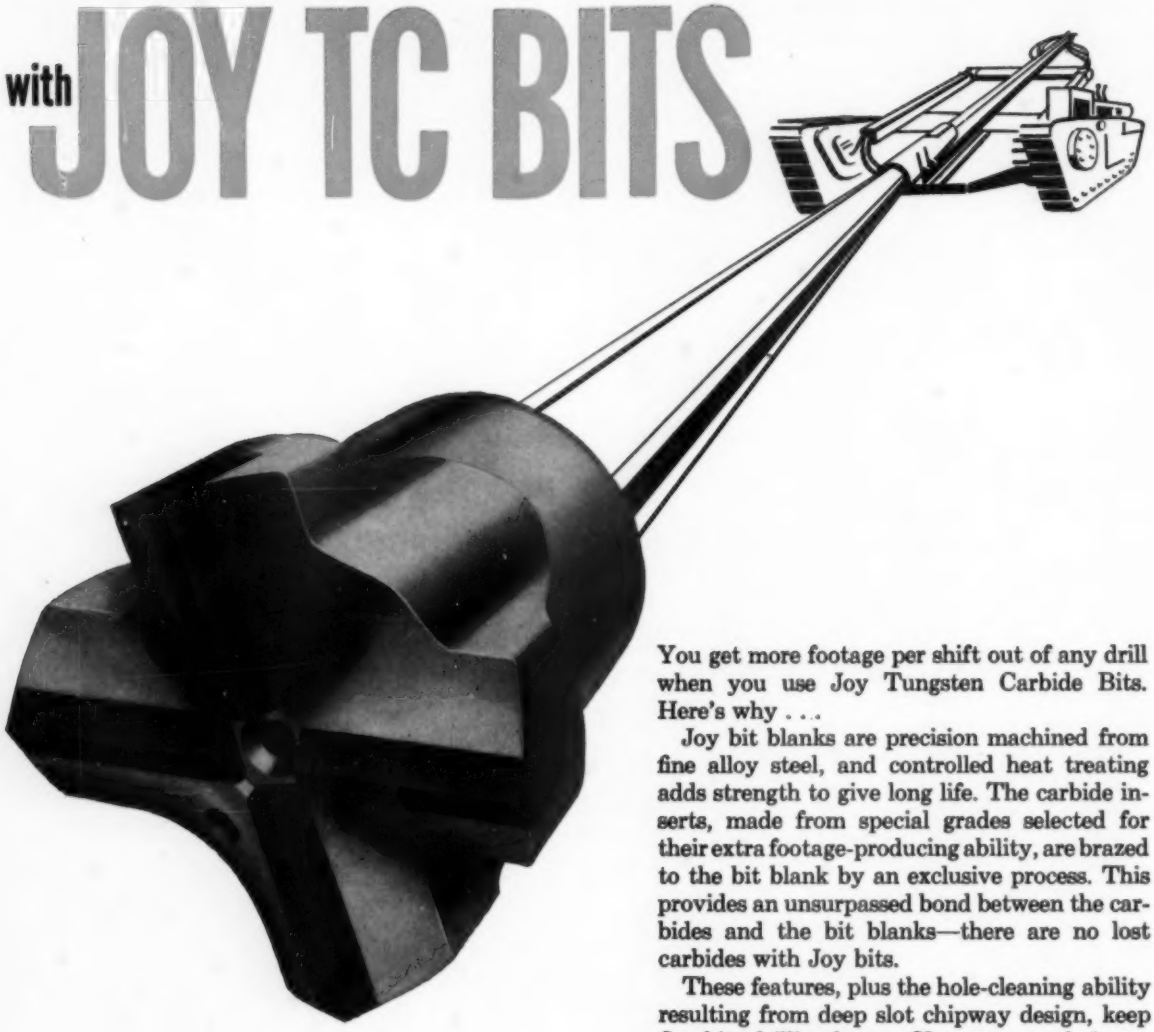

You get more footage per shift out of any drill when you use Joy Tungsten Carbide Bits. Here's why . . .

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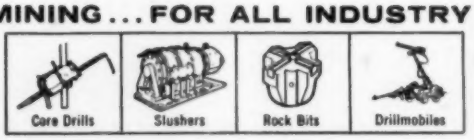

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Industrial Building Details, by Duane F. Roycraft, second edition, *F. W. Dodge Corp.*, 119 W. 40th St., New York 18, N. Y., 356 pp., $12.75, 1959—A reference tool that provides a collection of industrial architectural details drawn precisely to scale. Presentation has been simplified and brought up to date. Sharp, legible, clearly labeled drawings facilitate tracing or projection.

Tunnel Engineering, by Rolt Hammond, *The MacMillan Co.*, 60 Fifth Ave., New York 11, N. Y., 332 pp., $11, 1959—A comprehensive survey of tunneling methods and recent developments that have affected tunneling practice. A brief history precedes lining methods with practical examples, shield tunneling, and subaqueous tunneling.

Teifbohrtechnik, by Gottfried Prikel, *Springer-Verlag*, Vienna, Austria, 414 pp., $15.70, 1959—Deep drilling techniques are described in this companion volume to a 1957 book on drilling equipment. It covers stresses, bending and breaking points of drill rods, tool joints, and their stresses. Jet perforation and other special methods are briefly considered.

Principles of Geology, by James Gilluly and others, second edition, *W. H. Freeman and Co.*, 660 Market St., San Francisco 4, Calif., 534 pp., $7.50, 1959—A text which concentrates on the analysis of processes at work upon and within the earth, rather than presenting a catalog of descriptive facts and terms. This revision incorporates many significant advances in geologic science made in the last seven years.

Physicochemical Basis of the Analysis of the Paragenesis of Minerals, by D. S. Korzhinskii, *Consultants Bureau Inc.*, 227 W. 17th St., New York 11, N. Y., $7.50, 1959—Translated from Russian, this work is based on the author's 20 years investigation, with the purpose of supplementing the sketchy training of most geologists in physical chemistry. It is being sponsored by The Geochemical Soc.

Canadian Mines Handbook, 1959, *The Northern Miner*, 116 Richmond St. West, Toronto 1, Canada, 288 pp., $3 paper bound, $5 hard bound, 1959—This new edition details activities of thousands of mining companies and includes figures of production and profits for the first quarter, 1959, where available. All essential statistical data, directors, capitalization, etc., are provided.

The Iron and Steel Industry in Europe, *Organisation for European Economic Co-operation*, 2000 P. St., N. W., Washington, 6, D. C. 123 pp. plus statistical annex, $2.25, 1959—Trends and general economic conditions during the last half of 1957 and the first half of 1958, the supply and demand of steel, the production of pig iron and crude steel are a few topics covered. Investments and international trade are considered, and prices are listed before final conclusions.

STATE PUBLICATIONS

California
University of California
Berkeley, Calif.

The Cretaceous gastropod genus Biplica; its evolution and biostratigraphic significance, vol. 30, no. 6, $1, 1957.
Geology and paleontology of the Pleasanton area, Alameda and Contra Costa Counties, Calif., $2.50, 1958.

Colorado
Bureau of Mines
Museum Bldg.
14th Ave. and Sherman St.
Denver 2, Colo.

Annual Report, 1958, Colorado Bureau of Mines, gratis, 1959.

Illinois
State Geological Survey
Urbana, Ill.

Preliminary report on Ground-Water Resources of the Chicago Region, Cooperative Ground-Water Report 1, gratis, plus postage, 1959.
Stockpiling Illinois Coal for Coke, Circular 274, gratis, plus postage, 1959.
Limestone Resources of Extreme Southern Illinois, Report of Investigations 211, 25¢, plus postage, 1959.
Acidic Structural Groups in Illinois Coals, Report of Investigations 212, 25¢ plus postage, 1959.

Indiana
Geological Survey
Indiana Dept. of Conservation
Indiana University
Bloomington, Ind.

Adventures with Fossils, Circular No. 6, 45¢, 1959.

Kansas
State Geological Survey
University of Kansas
Lawrence, Kan.

Geology and Ground-water Resources of Clay County, Kansas, Bulletin 136, $1, 1959.
Geology and Ground-water Resources of Cloud County, Kan., Bulletin 139, $1, 1959.

Maine
State Geologist
Dept. of Economic Development
State Office Bldg.
Augusta, Maine

An Aeromagnetic and Geologic Reconnaissance Survey of Portions of Penobscot, Piscataquis, and Aroostock Counties, Maine, GP & G Survey 4, $1.15 (plus 3¢ in Maine), 1959.
An Aeromagnetic and Geologic Reconnaissance Survey of the Sidney-Augusta and Gardiner Areas, Kennebec County, Maine, GP & G Survey 5, $1.88 (plus 5¢ in Maine), 1959.

Minnesota
Dept. of Conservation
Div. of Waters
St. Paul, Minn.

Hydraulic Atlas of Minnesota, Bulletin 10, $5, 1959.

Mississippi
Geological Survey
University, Miss.

List of publications, gratis, 1959.

Montana
School of Mines
Butte, Mont.

Proceedings of the Symposium on Hydraulic Fill, 1958, $3.50.
Geologic map of the Northwest Flank of the Flint Creek Range, Granite County, Montana, Special publication 18, 40¢, 1959.
Progress Report on Geologic Investigations in the Kootenai-Flathead Area, Northwest Montana, Bulletin 12, gratis, 1959.

New Jersey
Bureau of Engineering Research
Rutgers University
New Brunswick, N. J.

Engineering aspects of glacial soils in the Newark metropolitan area of New Jersey, Bulletin 42, $1.50, 1959.

North Carolina
Dept. of Conservation and Development
Div. of Mineral Resources
Raleigh, N. C.

List of publications, gratis, 1957.

Oregon
Dept. of Geology and Mineral Industries
1069 State Office Bldg.
Portland, Ore.

Bibliography of theses on Oregon geology, Miscellaneous paper 7, 50¢, 1959.
Lode Mines of the Central Part of the Granite Mining District, Grant County, Oregon, Bulletin 49, $1, 1959.
Field Guidebook, Geologic Trips Along Oregon Highways, Bulletin 50, $1.50, 1959.

Pennsylvania
Topographic and Geologic Survey
Dept. of Internal Affairs
Harrisburg, Pa.

Geology of the Richland Quadrangle, Atlas 167D, $1.80, 1959.

(Continued on page 1182)

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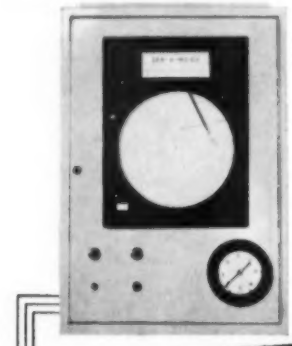

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BOOKS

(Continued from page 1081)

Tennessee

Dept. of Conservation and Commerce
Div. of Geology
G-5 State Office Bldg.
Nashville 3, Tenn.

Geology, Mineral Resources, and Ground Water of the Cleveland Area, Tennessee, Bulletin 61, $2, 1959.
Geology and Ground-Water Resources of the Dyersburg Quadrangle, Tennessee, Report of Investigations No. 7, $1.50, 1959.

University of Tennessee
Knoxville, Tenn.

A new map of the central basin of Tennessee, Contribution No. 198, reprint 1959.

Texas

Board of Water Engineers
1410 Lavaca St.
Austin, Texas

Records of Water-Level Measurements in Brazoria, Fort Bend, and Waller Counties, Texas, 1931 through June 1958, Bulletin 5904, gratis, 1959.
Records of Water-Level Measurements in Mitchell, Nolan, Sterling and Tom Green Counties, Texas, 1938 through 1957, Bulletin 5907, gratis, 1959.

Bureau of Economic Geology
The University of Texas
University Station, Box 8022
Austin 12, Texas

Bibliography and Index of Texas Geology, 1933-1950, University of Texas Publication 5910, $1.50, 1959.

Utah

State Engineer
Salt Lake City
Utah

A compilation of chemical quality data for ground and surface waters in Utah, Technical publication 10, 1958

Vermont

Vermont State Library
Montpelier, Vt.

The Geology of the Mount Mansfield Quadrangle, Vermont, Bulletin 12, 50¢.
The Geology of the St. Johnsbury Quadrangle, Vermont, and N. H., Bulletin, 13, 50¢.
The Geology of the Calvin Coolidge State Forest Park, 1959, 25¢..

Washington

Dept. of Conservation
335 General Administration Bldg.
Olympia, Wash.

Early Man in Washington, 50¢.
Flotation of Oxidized Zinc Ores From Washington, Bulletin 245, gratis.
Washington's Channeled Scabland, Bulletin No. 45, 50¢, 1959.
Prospecting in Washington, Information Circular No. 31, gratis, 1959.

West Virgina

Geological and Economic Survey
Morgantown, W. Va.

Caverns of West Virginia, v. 19 A, $2.04, 1958.

U. S. BUREAU OF MINES

Request free publications from:

Publications Distribution Section
U. S. Bureau of Mines
4800 Forbes Ave.
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IC 7902 Administration of the Federal Coal-Mine Safety Act 1952-1958.
IC 7903 Mining Methods and Costs, Baguio Gold Mine, Baguio Gold Mining Co., Baguio, Luzon, Philippine Islands.
IC 7895 Special Precautions for Multiple Short-Delay Blasting in Coal Mines.
IC 7896 Four Waterflooding Projects in Washington and Nowata Counties, Okla.
IC 7901 Determining the Explosibility of Mine Atmospheres.

FOREIGN PUBLICATIONS

British Commonwealth

British Information Services
45 Rockefeller Plaza
New York 20, N. Y.

In the May issue, page 478, the prices for British Information Services publications did not include freight costs, mailing and handling. In the future the prices of the New York sales office, which include freight costs, will be given. An additional 18¢ per shilling must be added to cover mailing and handling. The 8 items with corrected prices are as follows:
Geology of the Midlothian Coalfield, $3.78 plus 14¢ mailing and handling.
Geological Survey of Great Britain and the Museum of Practical Geology, 90¢ plus 5¢ mailing and handling.
The Efficient Use of Fuel, $6.30, plus 23¢ mailing and handling.
Classification of the Coal Measures of South Wales, $1.08, plus 8¢ mailing and handling.
The Economic Geology of the Stirling and Clackmannan Coalfield, Scotland, 90¢, plus 5¢ mailing and handling.
The Metalliferous Mining Region of South-West England, $18.90 plus 41¢ mailing and handling.
Notes on Grants Awarded by the Dept. of Scientific and Industrial Research to Research Workers and Students, 32¢ plus 5¢ mailing and handling.
Science and Technology in Western Germany, gratis.
British Phosphate Commission, 1958, Command Paper 715, 8d (approx. 12¢) plus 5¢ mailing.
Blue-Green Algae from the Middle Devonian of Rhynie, Aberdeenshire, Bulletin, Geology Vol. 3, No. 10, 1959, 8s.4d. (approx. $1.50) plus 8¢ mailing.
Memorandum of Award No. 1267. Rate of Wages of certain workers in the clay industries, 1959, 8d. (approx. 12¢) plus 5¢ mailing.
Mines and Quarries, Reports of H. M. Inspectors for 1958: **North Eastern Div.** 3s.10d. (approx. 70¢) plus 5¢ mailing; **North Western Div.,** 4s.4d. (approx. 78¢) plus 5¢ mailing; **Northumberland and Cumberland Div.** 2s.10d. (approx. 50¢) plus 5¢ mailing.
Statistical Summary of the Mineral Industry, Production, Exports and Imports, 1952-1957, 27s.6d. (approx. $4.95) plus 14¢ mailing.

Columbia University Press
International Documents Service
2960 Broadway, New York 27

Overseas Geology and Mineral Resources, Vol. 7, No. 3, 10s.7d. (approx. $1.90)
Methane. Drainage and Use of Methane from Coal-Fields. 1958, 6s.6d. (approx. $1.17).
Coal Statistics for Europe, Quarterly bulletin, Vol. VII, No. 3, 1958. 7s.7d. (approx. $1.37)

Ministry of Power
Safety in Mines Research Establishment
Portobello St.,
Sheffield 1, England

Calculation of the Relationships between Particle Number, Area, and Weight Concentration in Coal Mine Dust Clouds. S.M.R.E. Research Report No. 150, 2/6 (approx. 35¢).
Practical Aspects of the Foam-Plug Method of Fighting Large Mine-Airway Fires, S.M.R.E. Research Report 171, 2/6 (approx. 35¢).
Some Interim Notes on Methane Roof Layers, S.M.R.E. Research Report No. 164, 1/9 (approx. 23¢).
The Use of Models in the Investigation of Underground Methane Explosions, S.M.R.E. Research Report No. 163, 2/ (approx. 28¢).
Further Development of Twelve-Shot Exploders employing Artificial Lines, S.M.R.E. Research Report No. 161, 3/ (approx. 42¢).
A New Twelve Shot Exploder for Gassy Mines, S.M.R.E. Research Report No. 160, 2/3 (approx. 31¢).

Northern Rhodesia

Northern Rhodesia Chamber of Mines Year Book for 1957, available gratis from The Northern Rhodesian Chamber of Mines, P. O. Box 134, Kitwe, Northern Rhodesia, or American Metal Climax Co., 61 Broadway, New York, N. Y.
Northern Rhodesia Chamber of Mines Year Book for 1958, see above.

Venezuela

Division de Documentacion Geologica
Seccion de Biblioteca
Direccion de Geologica
Ministerio de Minas e Hidrocarburos
Caracas

Stratigraphical Lexicon of Venezuela, Special Publication No. 1, available free or in exchange for other publications.

ABSTRACTS

In This Issue: *The following abstracts of papers in this issue are reproduced for the convenience of members who wish to maintain a reference card file and for the use of librarians and abstracting services. At the end of each abstract is given the proper permanent reference to the paper for bibliography purposes.*

At Braden Copper—Safety Means Economy by *Stanley M. Jarrett*—Safe conditions and healthy environment increase the employe's job satisfaction and step up his efficiency. But only with training will employes accept safety as a responsibility and a challenge. Braden's safety organization and the results it has achieved are detailed in this paper, with policy changes, accident rates, and special areas such as silicosis and fire hazards covered. **Ref.: MINING ENGINEERING, November 1959, p. 1116.**

Developing Chuquicamata's Open Pit Haulage System by *Robert T. Laurich*—An efficient transportation system is a major factor in top mine output. Increased production demand in recent years has necessitated the improvement and expansion of the Chuquicamata system. Here is the story of its evolution, including facts on current production, mine equipment, trackage, communication, and future development. **Ref.: MINING ENGINEERING, November 1959, p. 1120.**

Industrial Minerals 1950-1958-1975, With Special Emphasis on Fluorspar by *Raymond B. Ladoo*—Paley report estimates and projections to 1975 for about nine minerals are compared with actual performance, 1950 to 1957. The fluorspar situation is considered in detail. It was concluded that the report underestimated world fluorspar reserves and rates of increase in consumption and production. Paley report views on phosphate rock as a major source of fluorine are questioned. Without major dependence on the phosphate rock source, known reserves give us less than 15 years supply at present rates of world consumption. Rate of growth of consumption of industrial diamonds was found underestimated in the Paley report. The situations of asbestos, mica, phosphate rock, potash, crystal quartz, and sulfur are briefly considered. **Ref.: MINING ENGINEERING, November 1959, p. 1123.**

Mining Laws of Mexico by *Luis G. Gutierrez and Agustin S. Segura*—Foreign investment in Mexico, particularly of American capital, has increased steadily since 1940. At present, however, these investments are less important to the Mexican economy than in earlier periods. In the last few years, local or Mexican capital has participated in most American investments in Mexico with the encouragement of the Mexican Government. The Government's favorable attitude toward industrial expansion has resulted in a fast growth of industrial activity, with mining investments in second place. This paper gives data on taxes, mining reserves, subsidies, types of mining concessions, and other aspects investors would want to consider. **Ref.: MINING ENGINEERING, November 1959, p. 1129.**

Pebble Milling Practice at the South African Gold Mines of Union Corp., Ltd. by *O. A. E. Jackson* (TP 59B17)—Steady progress in development of pebble milling in South Africa over half a century has brought the practice to its present state of efficiency. It has been established that for South African gold ores, the use of pebbles as grinding media is considerably more economic than addition of steel balls or rods. Furthermore, the cost of producing suitable pebbles is unlikely to advance as fast as the price of steel grinding media. Although steel is sometimes employed in primary milling, recent experience has shown that, in nearly all cases, it could be eliminated by the preparation of finer mill feed. The importance of accurate sampling and screen analysis cannot be too strongly stressed, and while pulp-density recording and controlling equipment is available, there is room for improvement. A futher valuable development would be the continuous recording, coupled with automatic control, of equivalent screen analysis. **Ref.: (MINING ENGINEERING, November 1959) AIME Trans., 1959, vol. 214, p. 1133.**

Time Aspects of Geothermometry by *R. J. P. Lyon* (TP 4814I)—There are marked discrepancies in depositional times derived from laboratory diffusion studies on naturally intergrown sulfides and those considered likely for most ore-forming processes, particularly where ores are formed or modified by regional metamorphism. Schwartz decided in 1931 that 475°C was the minimum temperature at which he could restore completely the solid solution from natural bornite-chalcopyrite intergrowths, but he also stated that reformed intergrowths could be preserved only if the time of cooling from 475°C to room temperature was less than 24 hr. The present article discusses the diffusion rates in two Australian ores that have been studied in detail. In Pine Vale ore, bornite, chalcopyrite, and tetrahedrite occur intergrown in fixed proportions. Heat treatment restores a homogenous solid solution at 500°C in 100 hr. The pattern of natural intergrowths can be simulated only if that solid solution is chilled to below 275°C in a few minutes. The ore must have been introduced 200 to 250°C hotter than that of the country rock and frozen in place.

In Aberfoyle ore, sphalerite, stannite, and chalcopyrite each occur containing the other two as intergrowths. Data obtained from the iron content of the sphalerite and from heat treatment of the ore indicate that deposition occurred at about 600°C. Chilling by the country rock had arrested the unmixing of the three blend-group solid solutions. Annealing experiments above 350°C led to further precipitation from the solid solutions and to significant segregation by solid diffusion within one week, indicating that both deposition and cooling of the ore were rapid processes—completed in a matter of days. The possibility that there are unsuspected variables in the diffusion experiments should be investigated. **Ref.: (MINING ENGINEERING, November 1959) AIME Trans., 1959, vol. 214, p. 1145.**

Factors Affecting the Cleaning of Fine Coals by the Convertol Process by *Shiou-Chuan Sun and W. L. McMorris III* (TP 59F205)—The purpose of the present investigation was threefold: 1) to determine the relative effectiveness of various oils and hydrocarbons for

(Continued on page 1084)

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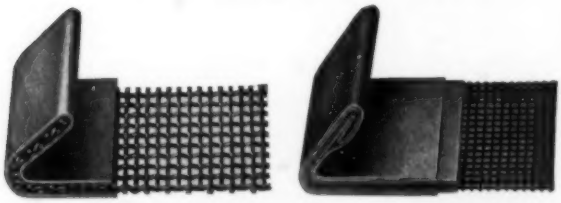

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ABSTRACTS

Continued from page 1083

recovering coal by the Convertol process, 2) to ascertain the behavior of coal pulps in the Convertol process, under various operational conditions, and 3) to compare Convertol with flotation in the recovery of fine coals. **Ref.: (MINING ENGINEERING, November 1959) AIME Trans., 1959, vol. 214, p. 1151.**

SME Meeting Papers: *The following abstracts of papers presented at SME meetings are given for your information. Copies of these papers are available* **only if followed by a preprint order number.** *These preprints are obtained on a coupon basis. The coupon books may be purchased from SME headquarters for $5.00 a book (10 coupons) for members of AIME or $10.00 a book for nonmembers. Each coupon, properly filled out, entitles the purchaser to one preprint. Mail completed coupons to Preprints, Society of Mining Engineers, 29 W. 39th St., New York 18, N. Y.*

The Influence of the Surface on Deformation Processes in Ceramic Materials by *Robert A. Lad*—Recent experiments with single crystals of the alkali halides and of MgO have shown that these materials possess a fair degree of inherent ductility at room temperature. These experiments have also served to demonstrate that the ductility and strength are extremely dependent on both the mode of specimen preparation and the treatment of the specimen after preparation. Many of the findings can be interpreted to indicate that the nature of the surface is the prime factor governing the behavior of the specimen. Cleavage introduces large members of dislocations into the surface regions of the crystal. Etch pit studies and experiments in which the surface layers were either removed or altered in a number of ways have shown that the dislocations introduced by cleavage can be caused to move by the application of very low stresses. It is proposed that these dislocations are responsible for the initial anelastic deformation observed in single crystals of NaCl, LiF, and MgO. They are also believed to contribute greatly to the conditions which give rise to the initiation of the crack which finally causes fracture. The ductility of cleaved crystals of NaCl can be substantially increased by treatments such as surface dissolution with water, annealing, and the deposition on the surface of a small quantity of silver. The application of silver by vacuum evaporation on crystallites of NaCl followed by hydrostatic pressing has yielded a ceramic body possessing a small degree of ductility. Copper or gold deposited in the same fashion does not increase the ductility. The implications of these experiments will be discussed. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Electrochemical Theory of Interface Reactions by *Henry Eyring* and *Taikyue Ree*—In this paper results are presented on continuing investigations on work reported at the 1959 Pittsburgh AIME meeting. King and Ramochandran (*The Physical Chemistry of Steel Making*, edited by J. F. Elliott, page 125, 1958) have shown that for the desulfurization of molten iron in contact with slags the degree of oxidation of carbon plus the oxidation of the metals just balances the transfer of sulfur from metal to slag. They attribute this to an electrical balance that must be maintained. The proposed use of the Nernst equation for this nonequilibrium system is not possible but absolute reaction rate theory provides us with the correct equation. Our model is that, in spite of convection, a thin layer of matter remains at the slag-metal interface across which ions must diffuse driven by the electrical potential and their concentration gradient. From this theory we are able to calculate with precision the rate of transfer of each species from metal to slag if the rate for any one species is given. These results will be presented at the meeting. This electrochemical theory of smelting is in some ways the reverse of theories such as that of Carl Wagner for corrosion. It makes use of similar considerations to those which have been successfully used in this laboratory for treating strain electrometry, the electrical potential across the membranes of living cells, overvoltage, adsorption kinetics and rates of electrochemical catalysis. All of these interfacial reactions obey the same general equation in which the activity of the various ions is modified by a common electrochemical potential. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Heats of Immersion. III. The Influence of Substrate Structure in the SiO_2-H_2O System by *W. H. Wade, R. E. Every*, and *Norman Hackerman* — Previous microcalorimetric measurements at this laboratory yielded somewhat unexpected results in that the heats of immersion per cm^2 of silica in water increased with increased particle size. This effect has been reinvestigated in the present work. Coarse crystalline quartz powder (100 mesh) was ground and sedimentation fractionated to obtain a wide spectrum of particle sizes. The possible explanation that this effect is due to a progressive loss of surface crystallinity with prolonged grinding times has been investigated by recrystallization of various particle sizes at the crystobalite conversion temperature (1470-1520°C). The assumption is that surface deformations would be removed at a temperature when the bulk lattice parameters are readily altered. This treatment uniformly increases the heats of immersion but does not completely remove the previously noted trend. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Adsorption of Polymers on Solid Interfaces by *G. Lopatin* and *F. R. Eirich*—The adsorption of high polymers on solid surfaces from solution exhibits many peculiarities with respect to the amounts adsorbed and the character of the adsorption equilibrium. Some of the work has been summarized before but newer developments indicate that this type of adsorption is beset with further complications. For instance, the chelating power of the polymer may be so great as to continually erode the surface. The solvent or pH effects may be such that relatively small changes lead to complete alteration of the character of the adsorption isotherm. Two new procedures have helped to overcome some of these difficulties. The one is a cycling of adsorption-desorption runs which eventually condition the surface to a constant behavior. The other is a turbidimetric titration which allows to determine polymer concentrations fast and with extreme accuracy. These techniques have been applied to the adsorption of acrylic polymers and copolymers and results will be discussed in detail. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Observations on Monolayer of Carbon-14 Labelled Stearic Acid, by *George L. Gaines, Jr.*—Monolayers of $C_{17}H_{35}C^{14}OOH$ have been deposited on a variety of solids including metals, glass, and mica. Deposition was accomplished from spread monolayers on water surfaces by both the Blodgett technique and the "touching" method, at a variety of film pressures, as well as by retraction from solution. The concentration of stearic acid molecules in the deposited monolayers can be related to that on the water surface from the counting measurements. Necessary corrections for absorption and backscattering of the radiation are considered.

The results indicate, as expected, that monolayers deposited from spread films are quite similar to those films in concentration. The tenacity of attachment to the substrate can be inferred from measurements of radioactivity remaining on the solid surfaces after various treatments. When films of stearic acid are absorbed from solution, however, a number of factors may lead to deposition of incomplete monolayers. The radio tracer technique clearly indicates this fact, even though the adsorbed films may appear to be complete monolayers on the basis of such measurements as contact angle determination. Data will be presented for the adsorption of stearic acid from both cetane and nitro-methane solution on metals, glass, and mica. *Joint Meeting SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Structure-Sensitive Aspects of Localized Corrosion in Aluminum by *O. P. Arora* and *M. Metzger*—A fundamental question of interest is the relation between the mechanisms of two types of localized corrosion, the type which is confined to the vicinity of structural defects, such as grain boundaries, and the type which consists of more or less randomly distributed pitting. This question was investigated in single-phase high-purity aluminum, principally by observations of the distribution and rate of corrosion in hydrochloric acid and other aqueous electrolytes with and without anodic current. The specimens contained structural imperfections—grain boundaries, subgrain (dislocation) boundaries and sicolocations—the nature and distribution of which had been studied by X-ray and other methods. The first part of the work was concerned with the mechanisms of corrosion localized at defects especially with determining the influences of impurities in the specimen and in the electrolyte. The second part was based on alteration of the chemical environment to make general pitting more favorable. The behavior of the structural defects, which were still influential, was used as a reference. It is concluded that the two types of localized attack observed in these studies have many aspects in common. A discussion of the similarities and differences is given. *Joint Meeting SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Static and Dynamic Attachment of Air Bubbles to Solid Surfaces by *J. Leja, John S. Carr*, and *Jack H. Schulman*—Contact angles have normally been considered to be static in concentrations of agents below their critical micelle concentration at the solid/liquid/gas interface. It is shown that if agents are chosen which form condensed monolayers at the air water interface and form association complexes with the agent chemisorbed on the solid surface, the contact angle can change quickly with time. This will enable an attached bubble to leave the surface. This time of attachment varies with the chemistry of the additive agent and the chemisorbed compound on the solid surface together with the chemistry of the solid or mineral surface. If the additive agent forms vapor films even at high concentrations and even also appreciably lowers the air/water surface tension, no change of contact angle is observed. A mechanism for this phenomena will be discussed in detail. This also showed that the system can be inverted such that particles attached to an air bubble will drop off the air water interface in a similar time period to the bubble detaching itself from a plate, with the same additives. This time of attachment can be controlled by frother type molecules and possibly be used for selective flotation of minerals. *Joint Meeting SME, MBD-American Chemical Society Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

An Electrochemical Study of the Silver Iodide Aqueous Solution System in the Presence of Sodium Laurate by *H. E. Bergna* and *P. L. deBruyn*—By means of an electrochemical titration technique the adsorption density of potential determining ions (Ag + and I −) was determined as a function of pAg and sodium laurate concentration at pH 7.6 and an ionic strength of 10^{-2}N. The ionic strength was fixed by sodium borate which was used together with boric acid as a buffer solution. Changing the pH from neutral to pH 7.6 resulted in a shift of the zero-poiny-of-charge of AgI from pAg 5.6 to pAg 5.7. The presence of sodium laurate resulted in a further and greater shift of the zero-point-of-charge to higher pAg values. For positive polarization of the silver iodide surface, the Ag-adsorption density increased with laurate concentration, whereas at high negative polarization the presence of sodium laurate did not seem to affect the adsorption of iodide ions. By a radiochemical technique the adsorption density of laurate ion at pH 7.6 and ionic strength 0.01 N was determined as a function of pAg and laurate concentration. The laurate adsorption density was seen to increase with decreasing pAg but remained finite even at high pAg values. The experimental results are discussed with reference to the present theory of the electrochemical double layer. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Effect of Surface Active Agents on the Strength Properties of Metals by *L. Nanis* and *J. H. Schulman*—The addition of oleic acid to the surface of copper wires effects a finefold decrease in rupture time at high load and a two to threefold increase in initial creep rate. These observations are in accord with those of Rehbinder. The so-called Rehbinder effect is examined from a phenomenological viewpoint of the actual mechanisms contributing to the observed strength changes. The separate phenomena are: 1) interaction between surface active agent and the natural oxide layer on the metal surface to produce mechanical changes in the oxide. 2) detergency of the surface oxide layer by the surface active agent. 3) chemical interaction between the oxide and the agent and/or its supporting medium, requiring the presence of an oxide solubilizing component, to cause chemical solution of the oxide layer. 4) restriction of oxygen access to the metal surface by a blanket of agent and/or supporting medium. 5) agent-metal interaction in monolayer dimensions with the possible change of surface free energy of the metal. 6) Catalytic action of the fresh metal surface to cause degradation of the agent and/or its supporting medium, resulting in new products which might take part in steps 3 and 4. Results of these steps are considered. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

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New ROM screen shakes off brutal battering

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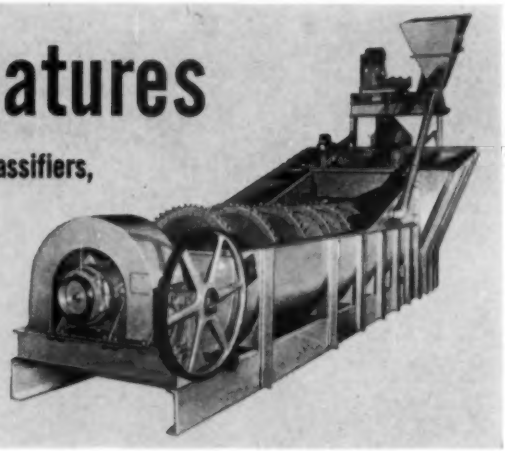

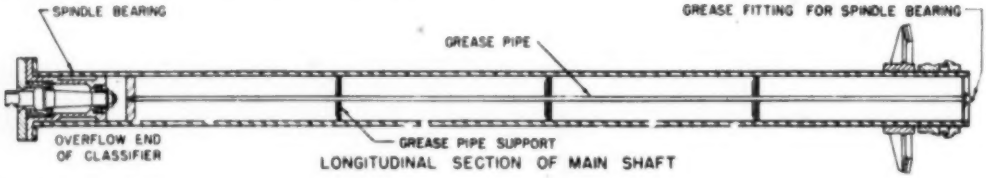

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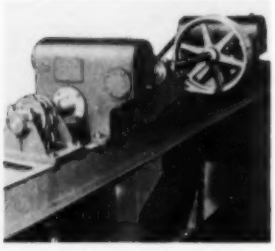
SUBMERGED BEARING

The patented submerged bearing has proven its advantages of durability, trouble-free operation, and ease of maintenance.

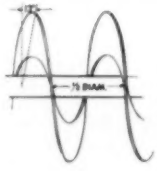
LUBRICATION

The submerged bearing is grease-gun lubricated through a pipe in the main shaft; thus the pipe is isolated from tank contents and protected against breakage. Grease fitting is at upper end of shaft for maximum convenience.



MECHANICAL LIFTING MECHANISM

The lifting device consists of chains, chain sprocket sheaves, and motor-driven or hand-operated reducer unit. Experience has proven this mechanical arrangement to be the most positive, with no possibility of slippage. Minimum maintenance. No packing glands or rods to become worn.

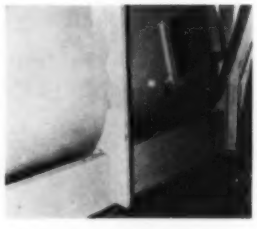


SPIRAL PITCH

50 years of experience has shown that the half-diameter pitch gives maximum raking capacity and results in less slippage and less wear than advanced pitch spirals.

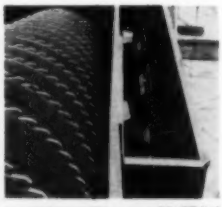
TANK SUPPORTS

Web beam substructure supports tank. There's no load to be carried by tank. This also reduces installation cost by eliminating need for extra sub-structures to support tank.



WEARING SHOES

Wearing shoes are made of various alloys, including Climax 42-A. Patented serrated wearing shoes are available for special applications. Special inner shoes are provided for heavy rake loads.



DRIVE

The bevel gear, V-belt drive has proven to be the most trouble-free and flexible. It permits mounting the motor, or motor-reducer, horizontally; and changing speeds quickly and inexpensively, by simply changing V-belt sheave ratio.

OVERFLOW BOX

An overflow box, with a pipe connection, is furnished as standard... requires only a single connection.

For complete information on Akins machines write for catalogs.

Manufacturing Division

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MANUFACTURERS NEWS

NEWS / EQUIPMENT / CATALOGS

Rear Dump

The new model S-18 has been added to the *Euclid* line of off-highway rear dump haulers. An overhung engine tractor with an Easton-built semi-trailer, the S-18

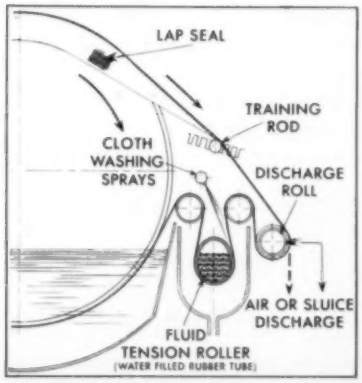
is powered by a GM 6-110 engine of 336 hp. Top travel speed with full payload is 25 mph. Trailer, designed to withstand impact and wear of heavy rock and abrasive ores, has struck capacity of 23 cu yd, heaped capacity of 26 yd. **Circle No. 1.**

Front-Discharge Skip

New front-discharge mining skips with doors that pivot from the top are announced by *Lake Shore Inc.* Main dump rollers are locked by safety hooks during travel. Enclosed chute extension cuts down on dust or splash in dumping. Photo shows front view, closed (at left) and open. **Circle No. 2.**

Cloth Filter Discharger

Peterson Filters & Engineering Co. has developed a device that provides thorough cleaning of cake from the cloth of drum filters, pre-



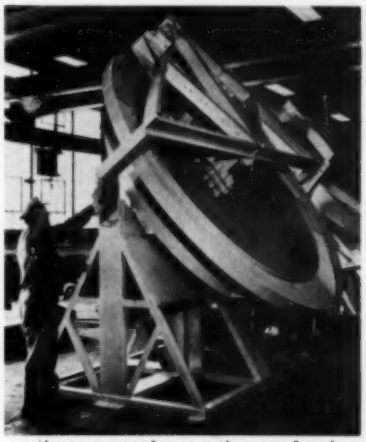
venting cloth binding and permitting good discharge even with fast filter cycles. Operation, as diagrammed above, includes use of fluid-filled tension roller to compensate for variable cloth stretch. **Circle No. 3.**

1960 Trucks

Heavy and extra-heavy duty 1960 trucks by *Ford* feature greater weight ratings and increased fuel economy. New line includes more than 200 conventional, tilt-cab and tandem models with gross vehicle weights ranging from 22,000 to 51,000 lb. Seven improved engines, including three Super Duty V-8's, provide better fuel savings. **Circle No. 4.**

Pelletizing Disks

Dravo Corp. has started production on a new line of Lurgi-developed pelletizing-mixing disks for



continuous agglomeration and mixing of fine granular solids. Disks are being made in four basic sizes: 3.25, 8.5, 12 and 16.5-ft diam. The smallest size will also be available for short-term rental for use in pilot plant studies. **Circle No. 5.**

Timbering Cage

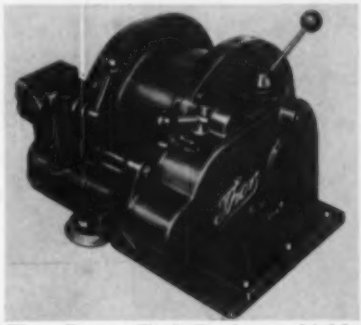
Machinery Center Inc. has a new cage designed for transporting a full set of timber down the shaft. Doors on the cage open horizontally to form a staging when in position. Two men can position shaft sets, timber safely and efficiently in a minimum of time with the new Lance timber cage. When the set is completed, the cage is raised and reloaded. **Circle No. 6.**

One-Use Carbide Bit

Le Roi Div. of Westinghouse Air Brake Co. has added one-use carbide insert drill bits to its line of CRD dust collecting bits. Available in three sizes—1⅜, 1½, and 1⅝ in.—the bits are of cross-hole, 5-hole design. They can be used interchangeably on the same ⅞-in. steel with Le Roi's all-steel one-use bits. **Circle No. 7**

Tugger Hoist

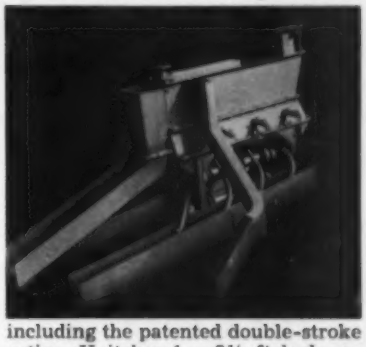
Developed for use in mining and construction, a new 1500-lb-capacity air-operated tugger hoist by



Thor Power Tool Co. has a highly responsive dual control system. The No. 1500 hoist is built for operation at floor level and has wire-rope capacity of 280 ft. Throttle control is mounted on hoist but can be removed for installation of remote control through connecting hoses. **Circle No. 8.**

Pilot-Size Jig

A *Wemco* Remer jig available in pilot plant size embodies all the characteristics of the large models,



including the patented double-stroke action. Unit has 1 x 3½-ft bed, capacity of 1 to 3 tph depending on size and type of material. **Circle No. 9.**

News & Notes

Christensen Diamond Products Co., long a producer of diamond bits and core barrels, announces it is entering the tungsten carbide field with its new Carbide Bit Div. . . . *Bucyrus-Erie Co.* has sold another huge stripping shovel, this one a 1050-B with 45-cu yd dipper for United Electric Coal Co. . . . Two crawler tractor models are in production at the new *Euclid* plant at Hudson, Ohio, the fifth Euclid manufacturing facility in the greater Cleveland area.

KENNEDY ROD MILLS

for the Mining Industry

Dependable operation in wet or dry grinding of material at low cost, with minimum maintenance—this is the reputation that KENNEDY Rod Mills enjoy.

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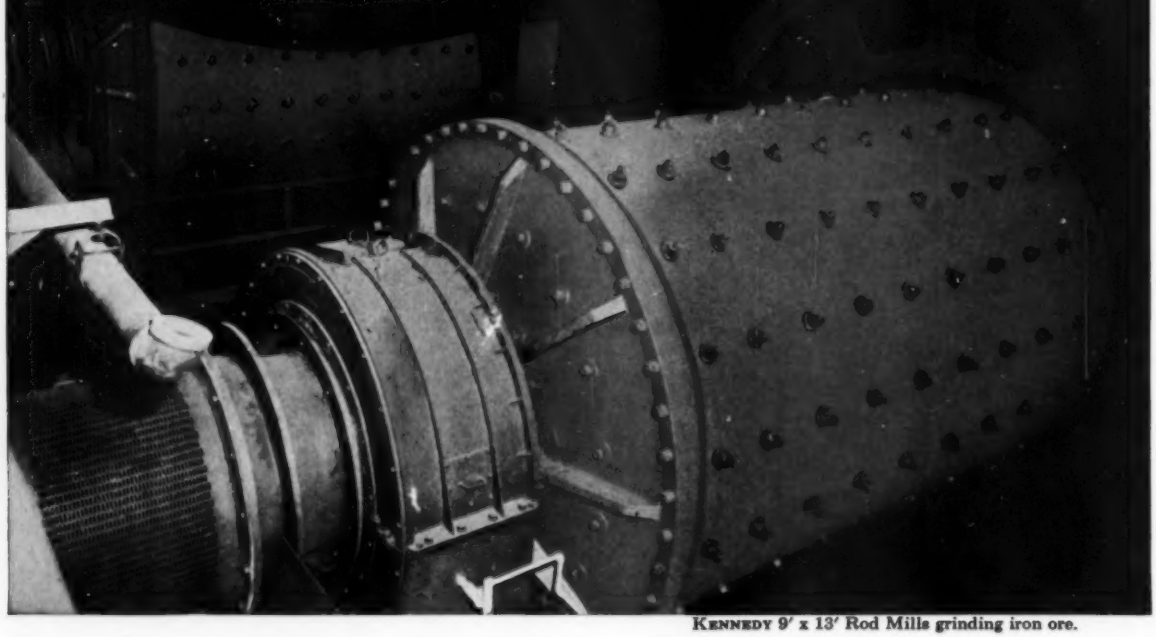

KENNEDY 9′ x 13′ Rod Mills grinding iron ore.

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- Large diameter trunnions
- Self-aligning bearings with adjustable sole plates
- Positive "Ferris Wheel" lubrication of main bearings
- Oil-tight bearing seals
- Motorized hydraulic lift to reduce starting torque
- Single helical cast steel gear and pinion

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Primary & Secondary Gyratory Crushers—Jaw Crushers—Roll Crushers—Ball Mills—Rod Mills—Air Swept Mills—Impact Breakers—Hammer Mills Belt Conveyors—Feeders—Vibrating Screens KENNEDY Research and Testing Services.

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MANUFACTURING & ENGINEERING CORPORATION

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(21) MINE LOCOMOTIVES: Bulletin GEA-6940 describes in eight illustrated pages the features and performance of *General Electric Co.*'s 27-, 37- and 50-ton mine locomotives. Ratings and dimensions, operation photos, and directions for simplified maintenance are included.

(22) DUMP TRAILERS: *Hercules Steel Products Co.* presents an equipment catalog covering dump bodies, dump trailers, and hoists in all ranges and models. Exclusive design and construction features and special truck equipment such as hydraulic tailgates are highlighted.

(23) MINE PUMPS: Self-priming mine pumps from *Gorman-Rupp Co.* are guaranteed to pump more mine water for more hours, at less operating cost, and to prime quicker than any other self-priming centrifugal pump. This guarantee is featured in a folder describing the line of mine-gathering pumps.

(24) FEEDERS: Cedarapids apron type feeders for aggregate handling equipment for bituminous mixing plants are illustrated in a folder from *Iowa Mfg. Co.* Reciprocating feeders are also included. They control feed, prevent choking, increase production, and reduce maintenance, according to bulletin FE-1.

(25) FILTER: *Dorr-Oliver Inc.* announces the availability of 8-page bulletin 7202 entitled "The American Filter," which describes the design, operation, and advantages of this disk-type filter for metallurgical, chemical, industrial, and food processing. Wash drawings and photographs show unit components in operation.

(26) SLUSHERS: Medium capacity, 15 to 40-hp slushers are the subject of bulletin 76-J from *Joy Mfg. Co.* These two-and three-drum haulers are designed for continuous heavy-duty operation, featuring fully self-energizing clutches and automatic brakes for operating ease.

FREE LITERATURE

(27) CONVEYOR BELT: Monobelt, a new type of patented flange-edge conveyor belting that eliminates the use of troughing idlers, is detailed in brochure NR-2 from *MonoBelting Corp.* Features and specifications, types and grades available, and applications are covered.

(28) ROPE: Seven products of the Wire Rope Div. of *Jones & Laughlin Steel Corp.* are described in a new series of five pamphlets. The products are: Centerfit wire rope,

cable laid slings, PlastiKore and SpringKore wire rope, JalKlamp and JalLoc slings, and oil field manila rope. Each pamphlet describes the applications for which the product is best suited.

(29) TRACTORS & SCRAPERS *Caterpillar Tractor Co.* presents a 2-color brochure outlining the operating features of the 619 wheel tractor and 442 Lowbowl scraper. Written to interpret the new operating features of this earthmover in terms of their importance to the contractor, the brochure (Form 33451) explains each individual component.

(30) HELICOPTER SERVICE: Exploration, construction, and supply by helicopter are among the topics covered in a booklet released by *Hiller Aircraft Corp.*, builders of the 305-hp 12 E helicopter. Photographs showing work in the field, brief performance specifications, and information on charter operator services are presented.

(31) BELT CONVEYORS: A practical handbook on the use and selection of standardized Pre-Bilt sectional belt conveyors has been released by *Link-Belt Co.* The 40-page book, 2779, lists the four belt widths, 22 components, and accessories.

(32) PUMPS: Chemical and process pumps from *Lawrence Pumps Inc.* are cataloged with detailed diagrams and photos, complete characteristics and specifications. Difficult pumping problems from molten sodium or liquid chlorine, liquid oxygen, hydrogen peroxide, or hot hydrofluoric acid have been successfully solved by Lawrence engineers.

(33) MATERIAL HANDLING SYSTEMS: Heavy duty savings for specially designed material handling systems are offered in a 192-page conveyor catalog from *Barber-Greene Co.* The company will design the most economical answer to special conveying needs, whether standardized or specialized components are necessary. Barber-Greene idlers present important advantages for longer life.

(34) MEN, METHODS & MACHINERY: This 52-page brochure tells how *Construction Aggregates Corp.* has devised practical cost-cutting solutions for engineering problems around the world. Included is the history of the Sensibar sandfill method. Unique projects involving land reclamation and stabilization, hydraulic stripping and dredging, and channel and port development are explained in detail.

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11

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61	62	63	64						

Students should write direct to manufacturer.

(35) PERFORATED METAL: How to specify perforated metal for coal and aggregate screens is described in 12 steps in a brochure from Cross Perforated Metals, *National-Standard Co.* The brochure details Cross Hexcreen, Conidure pierced sheets, and Rima wedge shaped wire screens.

(36) CRANE-EXCAVATORS: Model CR-350 self-propelled, 11-ton capacity truck crane excavator is detailed in a bulletin from *Schield Bantam Co.* Included is the complete line of Bantam attachments and standard and optional features. Actual applications are illustrated.

(37) SPEED REDUCERS: Two booklets containing detailed engineering data on *Hewitt-Robins Inc.* shaft-mounted, in-line helical and right-angle helical speed reducers have been published. Booklet J-19 covers shaft-mounted reducers and J-18 deals with in-line and right-angle helical drives.

(38) CRAWLER TRACTOR: Fourteen-page catalog MS-1318 available from *Allis-Chalmers Mfg. Co.* describes the HD-16 crawler tractor powered by the recently introduced Allis-Chalmers 16000 engine. A fold-out cutaway of the diesel engine's combustion chamber is included in the illustrations.

(39) MOTOR GRADERS: "More for Your Money" is the title of 16-page brochure MG-155 detailing the line of motor graders from *LeTourneau-Westinghouse Co.* Photos and diagrams describe operational and design features of the seven models, ranging from 67 to 190 hp. Two Power-Flow models are offered with full torque-converter transmissions.

(40) CONVEYOR PULLEY: A new belt conveyor pulley that increases conveyor belt life, has 25 pct greater strength, is concentric to .030 in., and is free from crown welds, has been announced by *Link-Belt Co.* Booklet 2540 contains detailed engineering and selection data.

(41) DRILLING MACHINES: A complete line of rotary gun drilling machines has been illustrated in a bulletin from *Stardrill-Keystone Co.* The Franks-Speedstar 30-AW rotary drilling machine, a medium weight, combination gun, conventional air and water rotary drill, is one item detailed.

(42) BELT CONVEYORS: Cedarapids belt conveyors for handling all types of bulk materials are illustrated in bulletin CON-1 from *Iowa Mfg. Co.* These conveyors are flexible, versatile, and made up of standard interchangeable units. Lattice frame, channel frame, and field conveyors are detailed.

(43) CRAWLER TRACTOR: *Allis-Chalmers Mfg. Co.* advertizes its HD-21 crawler tractor with 225-hp turbocharged diesel hydraulic torque converter drive in catalog MS-1234. Highlights of the 21000 engine and its combustion system, components making up the matched power train, and design and construction features are included in the data.

(44) PORTABLE CRUSHING PLANT: Bulletin COM-3 from *Iowa Mfg. Co.* describes the Cedarapids Commander, a portable crushing and screening plant with high capacity and maximum flexibility. Sixteen pages of photos and charts describe the components.

(45) CRANE: A colorful 12-page bulletin outlines the 30-ton Lorain Moto-Crane, model MC-430 of *Thew Shovel Co.* Details of the 8x4 wheel carrier with 3-position turntable mounting, 8 wheel power brakes, and rocker beam front bogie are included.

(46) AIR COMPRESSOR: A 24-page bulletin describing WN-112 stationary air compressor has been released by *Joy Mfg. Co.* Specifications, diagrams, cross-section drawings, and installation photographs tell the whole story in bulletin A-62.

(47) DRY PROCESSING EQUIPMENT: An 8-page color catalog illustrates *Sturtevant Mill Co.'s* full line of dry processing equipment. The new Pulver-Mill is detailed, plus data on air separators, blendors, mixers, crushing and milling machines, etc.

NEW FILMS

Earthmovers operators can see *The No. 619 Tractor*, a colorful preview motion picture showing *Caterpillar Tractor Co.'s* latest addition to its line of high speed rubber-tired machines. The 10½-min, 16-mm color film demonstrates the capabilities of the 225-hp tractor with matched 18-yd heaped scraper. Included are actual field service sequences illustrating the features of accessibility: the swing-away dash, the flywheel clutch, the cable control, differential and transmission. Contact your Caterpillar dealer.

The many and peculiar problems incurred in developing a major community from an area in the bush are graphically shown in the film *A City is Born* by the Jack Chisholm Film Productions Ltd., made for the government of Ontario. The film portrays the beginning of uranium mining enterprises and the influx of mining men which transformed the unknown area of Elliot Lake into one of the busiest spots in Canada. The color film runs 27 min and can be borrowed from the *Dept. of Mines or the Dept. of Planning and Development of Ontario.*

Pushbutton coal cleaning in one of the largest, most highly automated plants of its type is shown in *Link-Belt Co.'s* 16-mm film *Preparation Makes The Product.* The plant of the Clinchfield Coal Co. has a capacity of 1500 tph. The film, in sound and color, runs 19 min. It is available on letterhead request from Link-Belt Co., Dept. PR, Prudential Plaza, Chicago 1, Ill.

A new, 8-min film from *Caterpillar Tractor Co.* shows a 150-hp addition to the Cat motor grader line in a variety of applications. The 16-mm, sound and color film entitled *Cat No. 14* describes the motor grader as "big, in size, big in power, big in production, big in features." It is available from your Caterpillar dealer in English and French.

A dramatic and colorful film traces the production of ferro-alloys from the mining of ore, through smelting processes, to the shipping of finished products. *The Green Drum* is produced by *Vanadium Corp. of America*, runs for 24 min, is 16 mm with sound and color. Address requests, listing alternate dates, to The Green Drum, Advertising Dept., Vanadium Corp. of America, 420 Lexington Ave., New York 17, N. Y.

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No cost to you for this test service

ELIMINATE RISK!

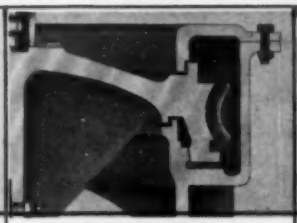
Let DENVER's 30 years of laboratory and world-wide field experience help you to eliminate risk—determine the right thickener for your needs—verify your own tests or recommendations of others. DENVER's experience covers a wide variety of materials plus the opportunity to relate test results to actual field operations. Laboratory tests, conducted at no cost to you, supply reliable data on

(A) Settling Rates
(B) Final Density
(C) Effect of Flocculating Agents
(D) Thickener Unit Area
(E) Overflow Clarity

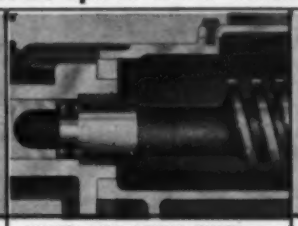
TESTS AT NO CHARGE—*These tests can assist you by eliminating risk of specifying a thickener that's too small to do the job or too large and costly for your needs.* Ship 5 gallon slurry sample prepaid to Denver Testing Division, 1755 Blake St., Denver, Colo.

Compare these distinctive features of DENVER Spiral Rake Thickeners:

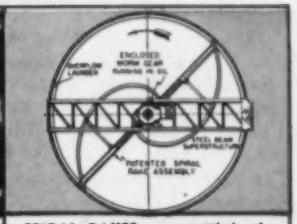
NEW ENCLOSED HOUSING protecting gear and drive mechanism is simple and rugged—available in sizes through 72" for light, medium, heavy and extra heavy duty. Tanks, steel or wood, in sizes to 150'. Write for Bulletin T5-B6.



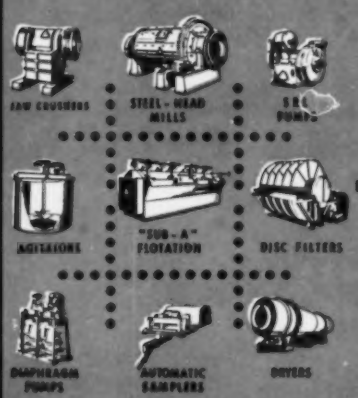
HIGH STRENGTH GEAR rides on replaceable no friction—no wear formica pads placed at periphery of the gear. Maximum stability, low bearing pressure and oil bath assure long life.



WORM AND WORM SHAFT are made from alloy steel, machined, case-hardened and ground. Shafts are proportioned to minimize deflection and retain full face gear-worm meshing.



SPIRAL RAKES move settled solids to center discharge port in only one revolution. Minimizes chance of choke-up, assures continuous operation. Why take 8 or 10 revolutions to bring pulp to the discharge cone when one revolution by the spiral rakes will do?



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DECO ENGINEERED STANDARD RELIABLE 24 HOUR SERVICE EFFICIENT

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Phone 21-1477

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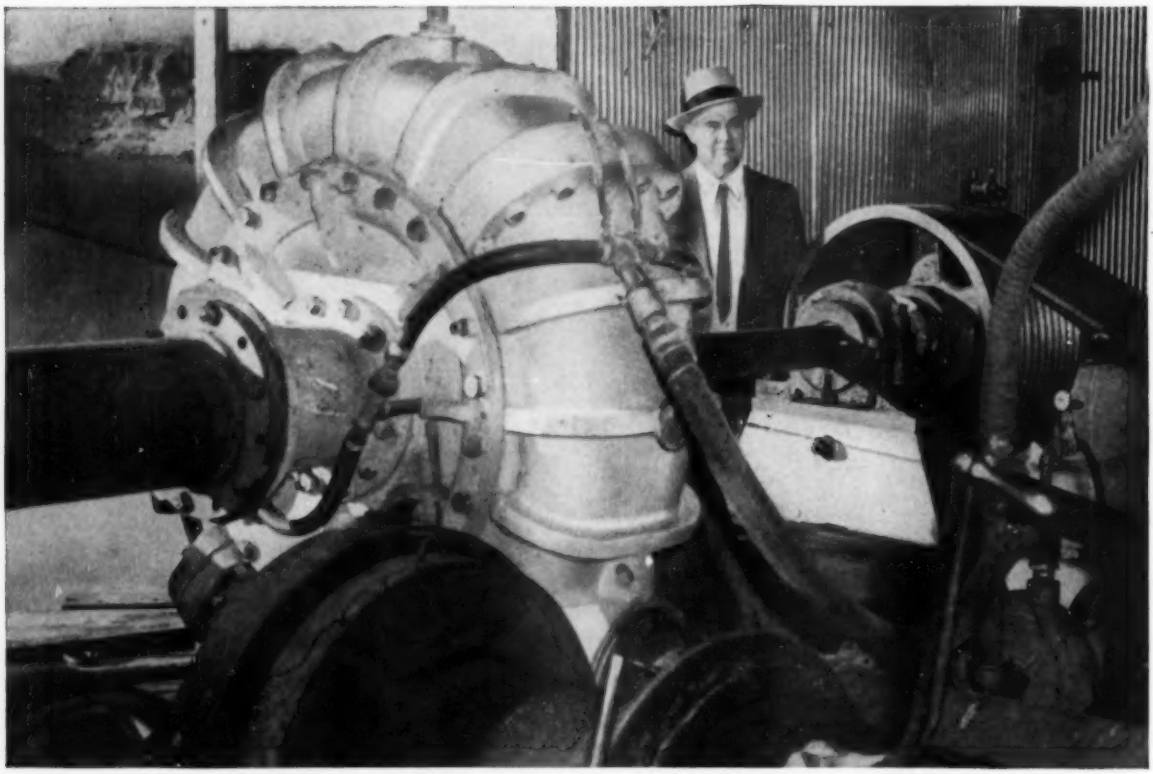
Marquez de Torre 370
Casilla 4930
Phone 41582



This dredge, operated by a prominent sand and gravel producer in Kansas, is equipped with a highly successful Thomas Ni-Hard pump installation.

Dredgers report Ni-Hard alloy pumps outwear others 4 to 6 times

From state after state come reports of the extraordinary service life of Thomas Ni-Hard pumps, made by Thomas Foundries, Inc., Birmingham, Alabama.

A West Virginia sand and gravel producer, for example, reports, "Since 1953, we have used only two Ni-Hard shell liners . . ."

A New Jersey company formerly replaced parts every 2 to 3 weeks . . . now says, "Today, we get approximately a year's service . . . a lifesaver."

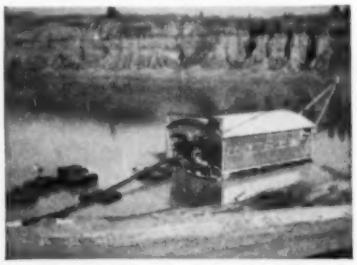
From Nebraska: – ". . . after almost two years of pumping has required no repairs, major or minor."

From Arkansas: – ". . . by far the most efficient and economical pump we have ever used, our 40-year records prove."

From these reports, it's easy to see that *longer pump life means lower operating costs!*

And a large part of the credit for the outstanding durability of Thomas Pumps goes to Ni-Hard* nickel-chromium cast iron.

This alloy is the most abrasion resistant of all commonly used cast materials, out-lasting many 4 to 6 times . . . regularly outwearing manganese steel in pump service.



What's more, Ni-Hard alloy has demonstrated remarkable impact resistance . . . being widely used for drop balls, crusher linings, and for many other severe applications. In impellers, casings, linings, and other parts for pumps, Ni-Hard alloy has virtually eliminated cracks or impact erosion caused by gravel and rocks.

If severe wear is running up your operating costs – it will pay you to find out what Ni-Hard alloy can do. Inco's booklet, "Engineering Properties and Applications of Ni-Hard" gives you essential details, and Inco's "Ni-Hard Buyers' Guide" lists authorized producers throughout the country. Write us for your free copy.

*Registered trademark

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N.Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Quebec Cartier Arranges for Project Credit

Quebec Cartier Mining Co., a U. S. Steel Corp. subsidiary, has completed arrangements with a group of American and Canadian banks for the establishment of a credit which will enable the company to borrow up to $200 million in U. S. funds at any time up to December 30, 1960. The money will be used to assist in the development of a project to mine iron ore in the Lac Jeannine area in Quebec. The project includes construction of a new harbor and loading facilities at Port Cartier, a 193-mile railroad from Port Cartier to Lac Jeannine, a 60,000-hp hydroelectric plant on the Hart-Jaune River, and the preparation of a large open pit mine and concentrator for the production of 8 million tons of concentrate per year.

SEC Permits Uranium Firms to Merge

A long-pending merger of five Atlas Corp. uranium affiliates has become effective, following issuance of the necessary order by the Securities & Exchange Commission. Lisbon Uranium Corp., Rio de Oro Uranium Mines Inc., Radium King Mines Inc., and Mountain Mesa Uranium Corp., were merged into Hidden Splendor Mining Co. which remains as the surviving corporation. The survivor, with assets valued at more than $65 million, becomes one of the largest independent uranium companies in the U. S.

New Coal Pipeline Plan Studied

Consolidation Coal Co., currently operating a 135-mile coal slurry pipeline in Ohio, and Texas Eastern Transmission Corp., pipe line operator, have joined in a study to determine if it is practical to pipeline coal from mines in West Virginia and Pennsylvania to utilities on the East Coast. Plans are indefinite but the line would be about 350 miles long and larger than the 10-in. line now in use by Consolidation.

Steel Strike in Fourth Month, Kaiser Signs

Negotiations between the steel-producing companies and the United Steelworkers union continued as the nation's steel strike entered its fourth month. The producers' Coordinating Committee, in bargaining for changes in local work rules it says will step up efficiency, has been strongly opposed by the union. Wage settlement differences are not a great gap in the talks and a settlement would probably come quickly after work rules terms are established. Kaiser Steel Corp., which had been an independent negotiator in the steel strikes of 1952 and 1956, again reached a separate settlement with the union. The company signed a two-year pact giving pension and welfare improvements in the first year and higher pay in the second year. Other steel companies gave no indication that they would follow the Kaiser lead.

Nonferrous Metal Sales

With 75 to 80 pct of the U. S. mine copper output lost through strikes, consumers are beginning to feel the pinch of diminishing supplies. Wire and brass mills expect lay-offs soon if metal inventories are not replenished. Mine producers still operating are quoting 31½¢ per lb. . . . The price of zinc has climbed to the general level of 12½¢ per lb, but tonnage sales are small. . . . Lead sales, on the upgrade recently, are still poor at 13¢ per lb.

MINING engineering REPORTER

Copper Strikes Cut Gold, Silver Output

August production of gold was down 14 pct from the month's level in the previous year and August output of silver dropped 21 pct from the July level. Production losses were laid to strikes at copper mines which recover the precious metals as byproducts.

Mission Concentrator Contract Awarded

American Smelting & Refining Co. has awarded a contract to Western-Knapp Engineering Co. for designing and engineering Asarco's 15,000-tpd copper ore concentrator for the Mission mine and plant project near Tucson, Ariz. Total cost of the copper project is estimated at more than $40 million.

Vitro Merger

Chemical and metallurgical operations of Vitro Uranium Co., Heavy Minerals Co., and Vitro Rare Metals Co. have all been merged into a new Vitro subsidiary, Vitro Chemical Co.

Ilmenite Deposit Sold

American Metal Climax Inc. has sold a deposit of high grade ilmenite in Ocean County, N. J., to Glidden Co. which will mine the ore and produce titanium dioxide to supply its large pigment plant in Baltimore. A concentrating plant is to be built on the site and completion is scheduled for late in 1961.

Plan Aid for Semi-Taconites

Minnesota tax help for mining the state's low-grade iron ores, as noted on this page last month, will be directed toward the *semi-taconites,* not intermediate ores as they were erroneously called. The semi-taconites of the Iron Range differ from the taconites in that they are relatively soft. Both are low grade.

New Germanium Plant

American Metal Climax Inc. intends to build a new germanium refinery at Carteret, N. J. The plant will be equipped to produce germanium dioxide from primary raw materials and scrap, and also to produce germanium metal for electronics use. Full operation is slated for 1960.

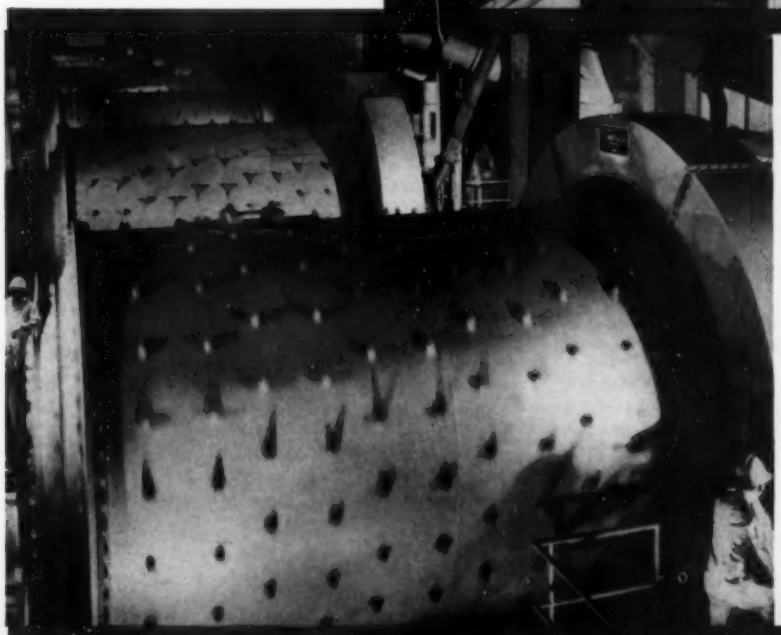
AEC Needs Geological and Mining Engineers

The Atomic Energy Commission's Grand Junction Operations Office at Grand Junction, Colo., is seeking applicants for the positions of geological engineer and mining engineer. Positions are presently available at Grand Junction, and at several field locations in the Western U. S. The geological engineer jobs start at $6285 and $7510 a year; the mining engineer positions at $7510 a year. Appointees receive vacation, sick leave, and other normal Federal benefits, and optional low-cost life insurance coverage. Further information and application forms may be obtained from the Personnel Branch, Atomic Energy Commission, Grand Junction, Colo.

SMIDTH

rotary kilns

For sintering, nodulizing, calcining, desulphurizing, oxidizing and reducing roasting. Coolers, precoolers, preheaters, recuperators.
Auxiliary equipment for Rotary Kiln Plants.



grinding mills

Ball mills, tube mills and multicompartment mills—open or closed circuit—wet or dry grinding.
Also airswept for grinding and drying.
Over 1250 Smidth Rotary Kilns and over 5000 Grinding Mills supplied all over the world.

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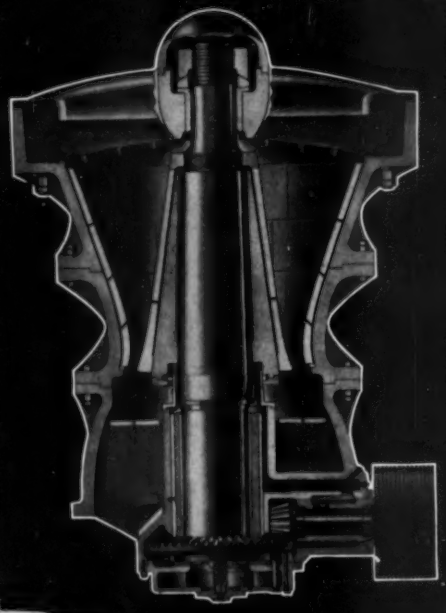
TC GYRATORY CRUSHERS



Traylor-made for primary reduction

Traylor engineers are the world's largest builder of giant 60" Gyratory Crushers. Here are some of the reasons the Traylor TC Gyratory Crusher is so much in demand:

- A straight line bar type spider, of heavy construction—simple but strong.
- Traylor original, self-tightening, bell head and curved concaves.
- The Traylor patented dust seal. A practical and efficient device for excluding foreign matter from the lubrication chamber.
- A positive outside automatic lubrication system.
- Bronze bushed eccentric bearing with pressurized lubrication.

. . . made in 7 sizes with feed openings 20" to 60" and capacities from 1,240 to over 32,000 tons per eight hour day are in use by many leading producers throughout the world.

For specifications and capacities, send for Traylor Bulletin No. 1126.

Shown above a 54" TC Gyratory Crusher in a portland cement plant.

GYRATORY CRUSHERS • JAW CRUSHERS
Traylor
ROTARY KILNS • BALL MILLS • APRON FEEDERS

See The Traylor Display at The Chem Show
Booth No. 495—New York Coliseum—Nov. 30 to Dec. 4

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Whatever your problem in flexible hose connections,

call the Man from Anaconda Metal Hose

Seamless: Of tin bronze (98¾% copper, 1¼% tin)—also corrugated stainless steel—in sizes ⅛" through 4" I.D. For conveying fluids, chemicals, etc., under conditions of flexure or vibration and to allow for misalignment. Reusable (mechanical type), soldered or welded fittings.

Stripwound: Constructed from brass, bronze, aluminum, galvanized or stainless steel. Sizes ½" through 8" I.D. A rugged type of hose for general service as steam, oil, water, particularly where the hose is handled manually. Fittings: soldered or heatproof (packed-on).

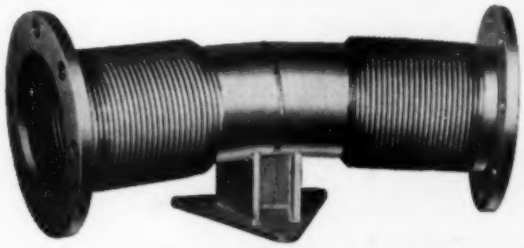
Type UI: Interlocked unpacked hose in galvanized steel, stainless steel, aluminum, etc. Sizes through 8" I.D. For ventilating ducts, dust collection, engine exhausts, exhausts at grinding machines, bottle chutes, drain lines, protective casing for flexible hose assemblies.

Diesel: Heavy-duty steel exhaust and air intake hose. Sizes 2" through 16" I.D. Designed for rugged, heavy-duty use. Helical corrugations with open or closed pitch. Also in stainless steel (type Y-21) for corrosive applications.

Flexpipe: Takes up travel in piping, connects misaligned ports, dampens noise and vibration in piping. Standard sizes and lengths. Available in bronze, stainless steel, steel; in sizes ¼" through 16" I.D. with NPT fittings, flanges or welding nipples.

Teflon* Anaconda flexible connectors of Teflon with stainless steel wire braid for use with pipe sizes from ⅛" through 1¼". Available in a wide variety of standard hose assemblies complete with fittings.

*Teflon is a DuPont trademark for its fluorocarbon resins.



AX Tubing: Large diameter tubing for big, tough jobs. Available in Type 321 Stainless Steel, and other metals and alloys. Sizes from 4½" through 14" I.D. Designed to handle axial and lateral movement—while conveying large volumes of liquids or gases—for bulkhead seals, etc.

FREE TECHNICAL SERVICE. Anaconda Metal Hose specialists are constantly working with design engineers on special flexible connectors and hose to meet new problems. Having broad experience working in stainless steel, other steel alloys, Monel, copper alloys, aluminum, and Teflon, they can save you considerable time and money in designing the flexible connector best suited for any of your jobs.

Our specialists are available to you through Anaconda Metal Hose representatives in leading cities—see listing "Metal Hose" in the Yellow Pages. Or write: Anaconda Metal Hose Division, The American Brass Company, Waterbury 20, Conn.

ANACONDA® METAL HOSE

The Mining Machines You'll

YESTERDAY, Marion rail-mounted steamers were the marvel of their era, taking back-breaking labor out of loading and helping giant industries move toward big production.

Field tested, ready and waiting, these are the Marion machines that will help write the next chapters of progress in world mining history.

Teamed with larger haulage units, they cut wider benches, cut track moving time where rail cars are used and open new areas of low-unit-cost efficiency in the pit.

Big, bold and burly, they load more, faster, cheaper.

You get MORE *with* MARION

Need in the 1960's

The Marion 4161 and Marion 151-M cut open pit mining costs so consistently that they became the standard machines for the industry. That history will be repeated on a bigger scale as the Marion 181-M and Marion 191-M come into their own in the copper and iron pits in the decade ahead.

Far-sighted management men with a reputation for cashing in on the advantages of being the first to adopt new operating efficiencies will want the details about these great new Marions. Let's talk facts and figures.

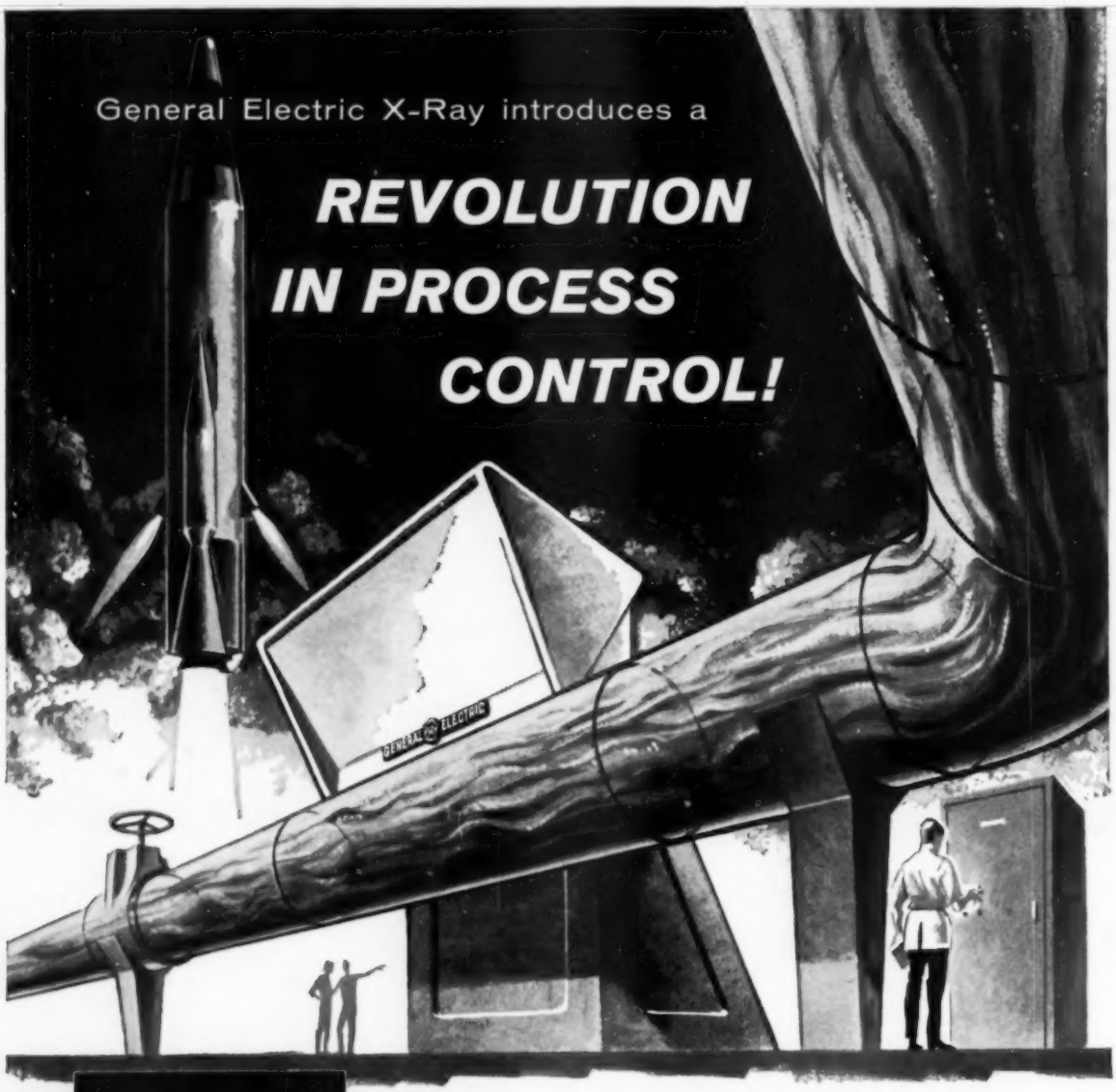
TODAY, the daily output of Marion 4161 and 151-M machines in the open pit mines sets industry standards for costs. Dependable Marions will continue to mine a big percentage of the world's ore for years to come.

MARION POWER SHOVEL CO. — MARION, OHIO

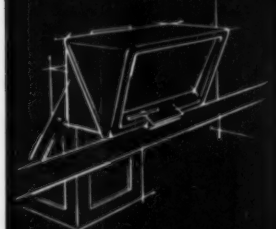
A Division of Universal Marion Corporation

General Electric X-Ray introduces a

REVOLUTION IN PROCESS CONTROL!



Analyzes materials continuously, or in individual samples —



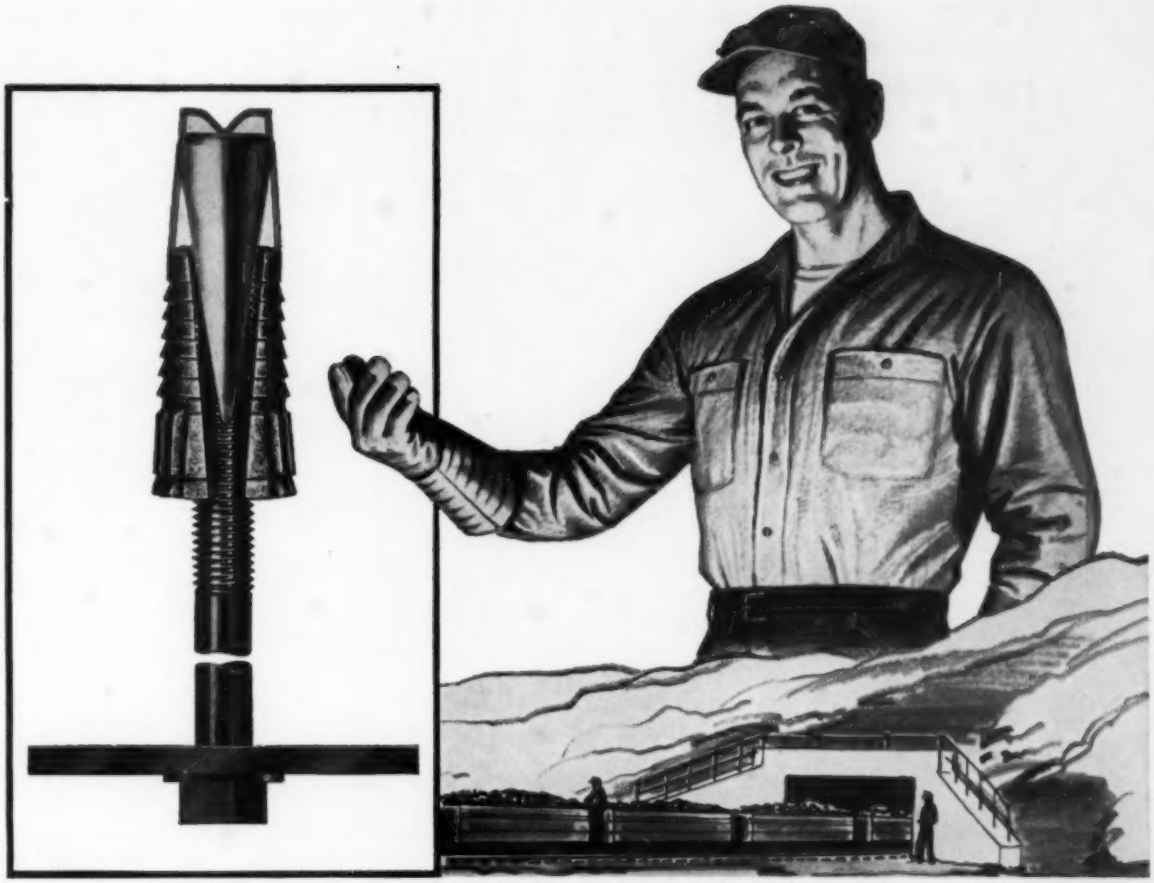
- gases
- liquids
- solids
- mixtures of all three
- flowing slurries
- moving strips or wires
- a host of other forms

XEG scans materials in production, writes an on-the-spot x-ray analysis of up to 5 elements simultaneously

Here at last are means for wiping out a long-standing blind spot in process control: *XEG allows moment-by-moment surveillance of materials composition, right on the production line* — can detect and measure up to five elements at a time! XEG is a new and revolutionary *x-ray emission gage* — another exclusive product of General Electric "know how." Lends itself to more applications than you can imagine. Reveals quality . . . delivers facts on composition for rapid-fire, continuous feed-back to process control. Yet XEG requires no skilled operator! Ask your G-E x-ray representative for full details on potentials. Or simply write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Room ME-114.

Progress Is Our Most Important Product

GENERAL ELECTRIC



CF&I Rock Bolts with Pattin Shells give maximum anchorage

The Image of CF&I stands for a line of quality steel products that are prominent in the mining industry.

One of these—CF&I Expansion Rock Bolts with Pattin Shells—are widely used because of several exclusive design features. The double expansion of Pattin Shells gives parallel contact along the entire length of the hole, thus ensuring maximum anchorage in any type of rock. The Pattin design provides a maximum resistance to load with minimum displacement.

High strength steel—made to American Standard Specifications for roof bolting materials—provides an ample factor of safety. And CF&I Rock Bolts have been fully safety-tested, thoroughly proven in use.

Maximum utilization of available work space and ventilation facilities is possible with CF&I Rock Bolts, since cumbersome, space-consuming timbering methods are often unnecessary. When used with CF&I's Realock Metallic Fabric for lagging, CF&I Rock Bolts offer proved initial-cost savings up to 35% over timber set costs.

CF&I Rock Bolts with right hand threads are available in ¼", ⅜" and ⅞" diameters, and in four different sizes of Pattin Shells. The ¼" bolts are also made with left hand threads for tightening by drilling machines.

CF&I also makes a complete line of 1" Wedge Type Rock Bolts, as well as ¼" expansion type slusher pins.

OTHER CF&I STEEL PRODUCTS FOR THE MINING INDUSTRY

CF&I Grinding Balls • CF&I Grinding Rods • CF&I Mine Rail and Accessories • CF&I-Wickwire Rope • CF&I Industrial Screens • CF&I Grader Blades

A 20-minute Rock Bolting color movie "Make Mine Safety" is available for showing at no charge, through the CF&I office nearest you.

CF&I STEEL

MINING PRODUCTS

THE COLORADO FUEL AND IRON CORPORATION

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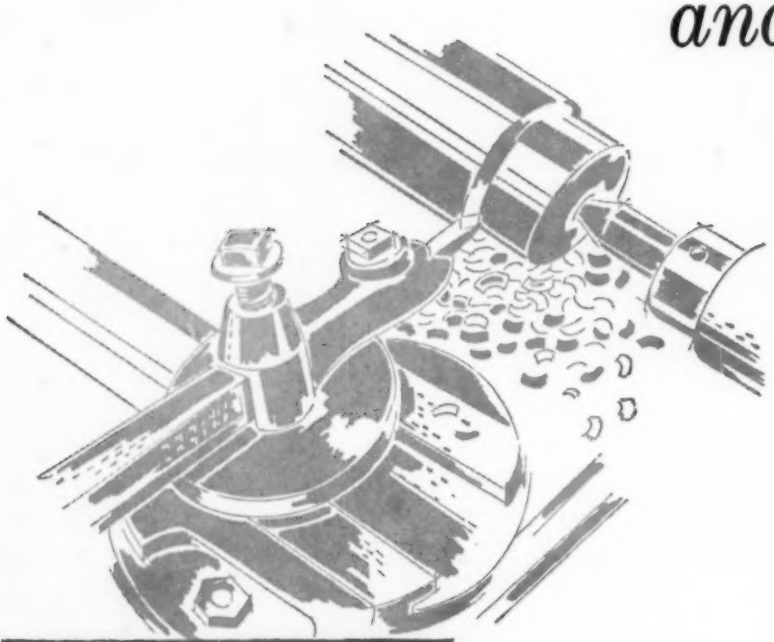
In the West: THE COLORADO FUEL AND IRON CORPORATION—Albuquerque • Amarillo • Billings • Boise • Butte • Denver • El Paso • Farmington (N.M.) • Ft. Worth • Houston Kansas City • Lincoln • Los Angeles • Oakland • Oklahoma City • Phoenix • Portland • Pueblo • Salt Lake City • San Francisco • San Leandro • Seattle • Spokane • Wichita

In the East: WICKWIRE SPENCER STEEL DIVISION—Atlanta • Boston • Buffalo • Chicago • Detroit • New Orleans • New York • Philadelphia

SULPHUR

ONE OF THE FOUR STRONG PILLARS OF PROCESSING

SULPHUR *and* STEEL



This fact may not be too well known: the steel industry consumes about 7% of all the elemental Sulphur or Sulphur existing in the form of sulphur gases, etc., used in this country. Most of this Sulphur serves the steel industry in the form of Sulphuric Acid where it is used in pickling steel products but also to a considerable extent in plating them. And certain machine steels carry an appreciable amount of 'planted' Sulphur to impart desirable machining qualities. Seven percent of the total elemental Sulphur and equivalent Sulphur tonnage is quite substantial. Its use in steel emphasizes the importance of Sulphur to our whole economy. Much of this tonnage of steel-used Sulphur starts out at our mines in Texas where we serve as a major supplier of Sulphur to the manufacturers of Sulphuric Acid.

SULPHUR PRODUCING UNITS

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• Moss Bluff, Texas • Fannett, Texas
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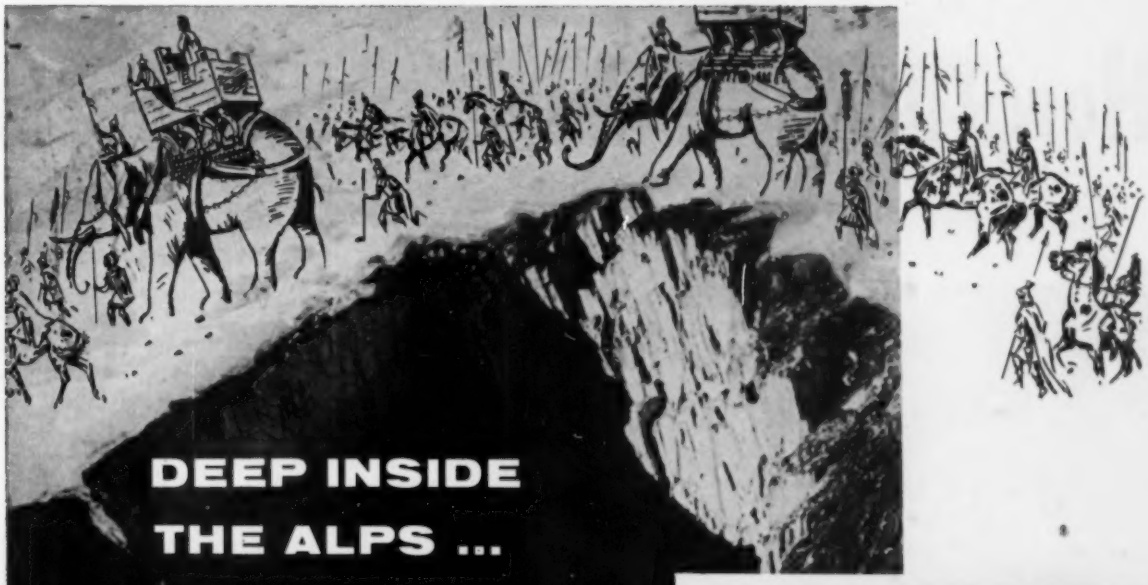

DEEP INSIDE THE ALPS ...

EIMCO helps make an ancient dream come true

Eimco tractor-excavator near the Mont Blanc tunnel site and the Eimco-Italia service van.

Entrance to Mont Blanc tunnel from the Italian side where Impresa Condotte d'Acqua has bored more than 500 meters of tunnel using Eimco equipment.

Ever since Hannibal made his historic crossing of the Alps, men have dreamed about tunneling a roadway through Europe's highest peak, 15,781 foot Mont Blanc. This tunnel now is becoming a reality with Eimco 105 Tractor Excavators being used for mucking. This will be the world's longest (7.5 miles) vehicular tube and will link France and Italy with an all-weather highway when completed in 1961.

Tunnel crews working from both the French and Italian sides are using Eimco equipment — because Eimcos have a reputation around the world of doing rock and earth moving tasks efficiently, safely and F-A-S-T!

FLEXIBLE POWER FOR TUNNEL WORK — The Big E lifts large chunky boulders, over 10 tons, without need for breakup . . . Cushioned torque converter, unidrive power, with up to 39,000 pounds of breakout force, automatically matches the gear to the load!

EASE OF OPERATION — In restricted areas like a tunnel, the Eimco Excavator really stands out. No turning to discharge load. Fastest possible loading cycle. Minimum operator fatigue because there is no more tugging at levers nor pushing on foot pedals. Operators get instant response from finger-tip controls.

LOW MAINTENANCE — Superior, quality controlled construction from the pouring of metal to finished product . . . sealed anti-friction bearings, extra heavy heat treated steel pins and bushings . . . Simplicity of Unidrive transmission . . . No master clutch to wear out or service . . Just a few of the reasons why Eimco machinery is on the job day after day, hour after hour.

For more information about why EIMCO is the machine for your specific operations, contact an EIMCO sales-engineer at the sales office nearest you, or write to The Eimco Corporation, P.O. Box 300, Salt Lake City 10, Utah

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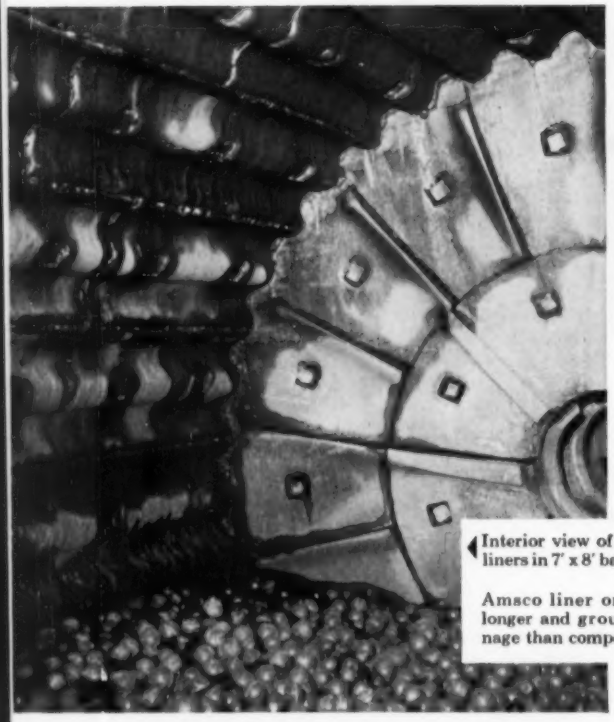
How AMSCO helps you HANDLE



Interior view of Amsco double wave liners in 7' x 8' ball mill, using 2" balls.

Amsco liner on left lasted 123% longer and ground 134% more tonnage than competitive liner on right.

Bucyrus 88 D four-yard bucket, equipped with Amsco Simplex 2-part Teeth, removing rock for power station. All of Tuscarora Constructors' shovels used for rock excavation are equipped with Amsco Simplex Teeth.

MORE TONS PER DOLLAR

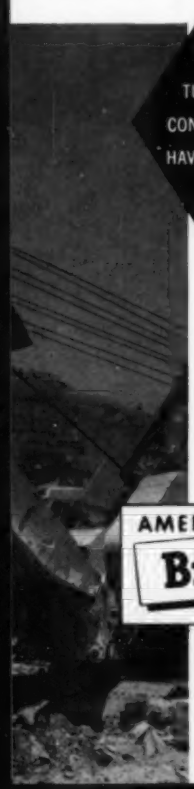
Read how AMSCO Mill Liners and Dipper Teeth are outlasting competitive parts in severe service

AT A LARGE NEW YORK ZINC MINE...

THEY'VE DOUBLED SERVICE LIFE WITH AMSCO CHROME-MOLY BALL MILL LINERS

Amsco double wave chrome-moly liners are used on an Allis-Chalmers 7′ x 8′ ball mill at this large northern New York zinc mine. The mill is operating *24 hours a day, six days a week*... grinding rod mill discharge consisting of sphalerite, pyrite and the balance silicate and limestone gangue.

These Amsco liners ground 670,000 tons during their 29-month life... as against an average of 286,000 tons and 13-month life for the type of liners previously used. That adds up to over *100% increase in service life*. In addition to their longer life, another fact that impresses the operators about Amsco liners is that there's no circumferential grooving until the very end of their service life.



TUSCARORA CONSTRUCTORS HAVE FOUND...

AMSCO 2-PART DIPPER TEETH ARE "BEST-WEARING TEETH WE'VE EVER USED"

At the Niagara Power Project, Tuscarora Constructors are building the power station and pumping station. They're digging almost entirely in rock, working their dippers 24 hours a day, six days a week.

Dell Lundmark, Equipment Superintendent for Tuscarora, was responsible for selecting Amsco 2-part reversible teeth for his dippers. He'd heard of their fine performance elsewhere, and now describes them as the "best wearing teeth we've ever used". He says the design of the teeth is very good for rock, and adds, "We're getting *15% to 20% longer wear* than from competitive 2-part teeth".

Approximately 10,000 tons of rock are handled before the teeth are turned over ... and tips are easy to replace when completely worn.

This combination of a new alloy steel, plus the design features engineered into the Amsco Simplex Teeth, are causing equipment superintendents everywhere to change to Amsco for better, lower cost digging.

AMERICAN Brake Shoe COMPANY

AMSCO

American Manganese Steel Division • Chicago Heights, Ill.

Other Plants in: Denver • Los Angeles • New Castle, Dela. • Oakland, California • St. Louis

In Canada: Joliette Steel and Manitoba Steel Foundry Divisions

UPGRADING AND SHARP CLASSIFICATION WITH KREBS INTEGRAL 2-STAGE CYCLONES*

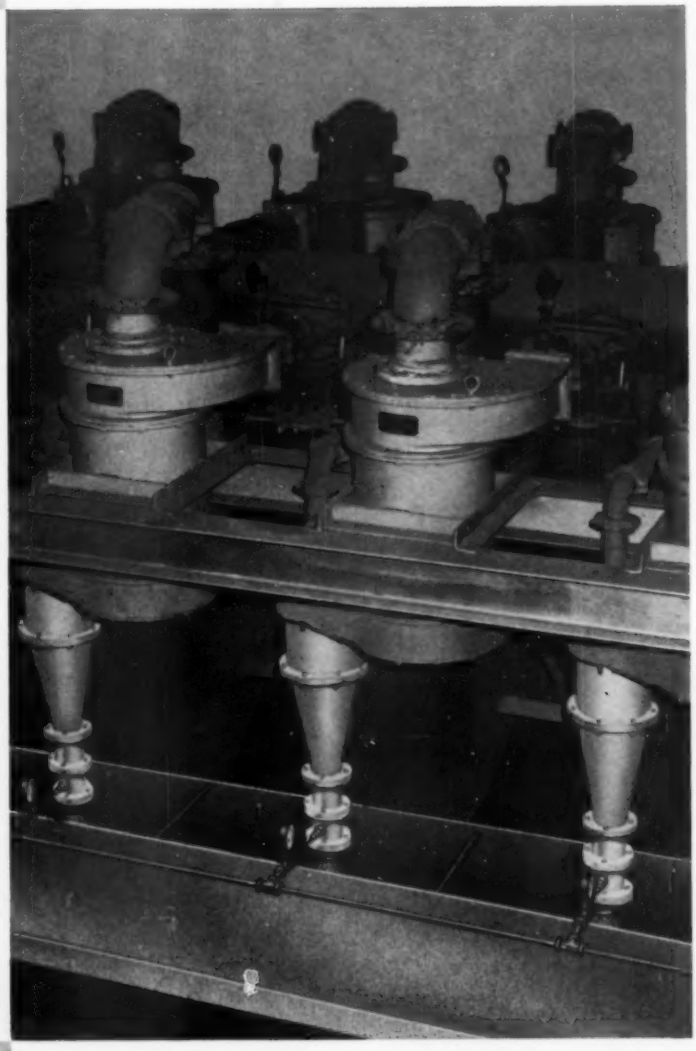
The three-products feature of this cyclone design creates profits by upgrading ores of iron, chrome, manganese, copper, gold, glass-sand, alumina, and other industrial minerals. The Krebs integral two-stage cyclones are a standard method used ahead of spirals for upgrading in iron washing plants—see photo.

Applications are diverse. A copper concentrator uses them on full tonnage, rejecting an essentially minus 15 micron slime from the primary cylinder, with the secondary overflow being the flotation feed, and the small tonnage of underflow reground and recycled.

While most of the 20 Models and the vast majority of Krebs Cyclones in operation are single-stage, 70 plants have installed the two-stage cyclones to obtain the most efficient upgrading.

This is only one of many Krebs Cyclone design developments in the past 10 years. Recent work indicates even wider applications and economic advantages with the Krebs integral two-stage cyclones.

Where upgrading or a sharp classification may be significant to your operations, we invite you to make use of our Pilot Plant facilities and staff of cyclone specialists.



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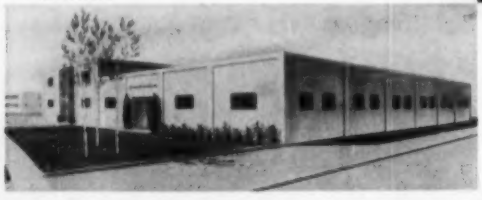

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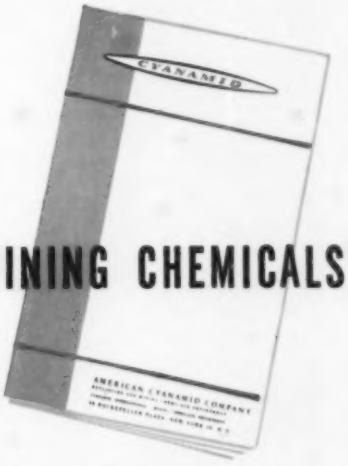

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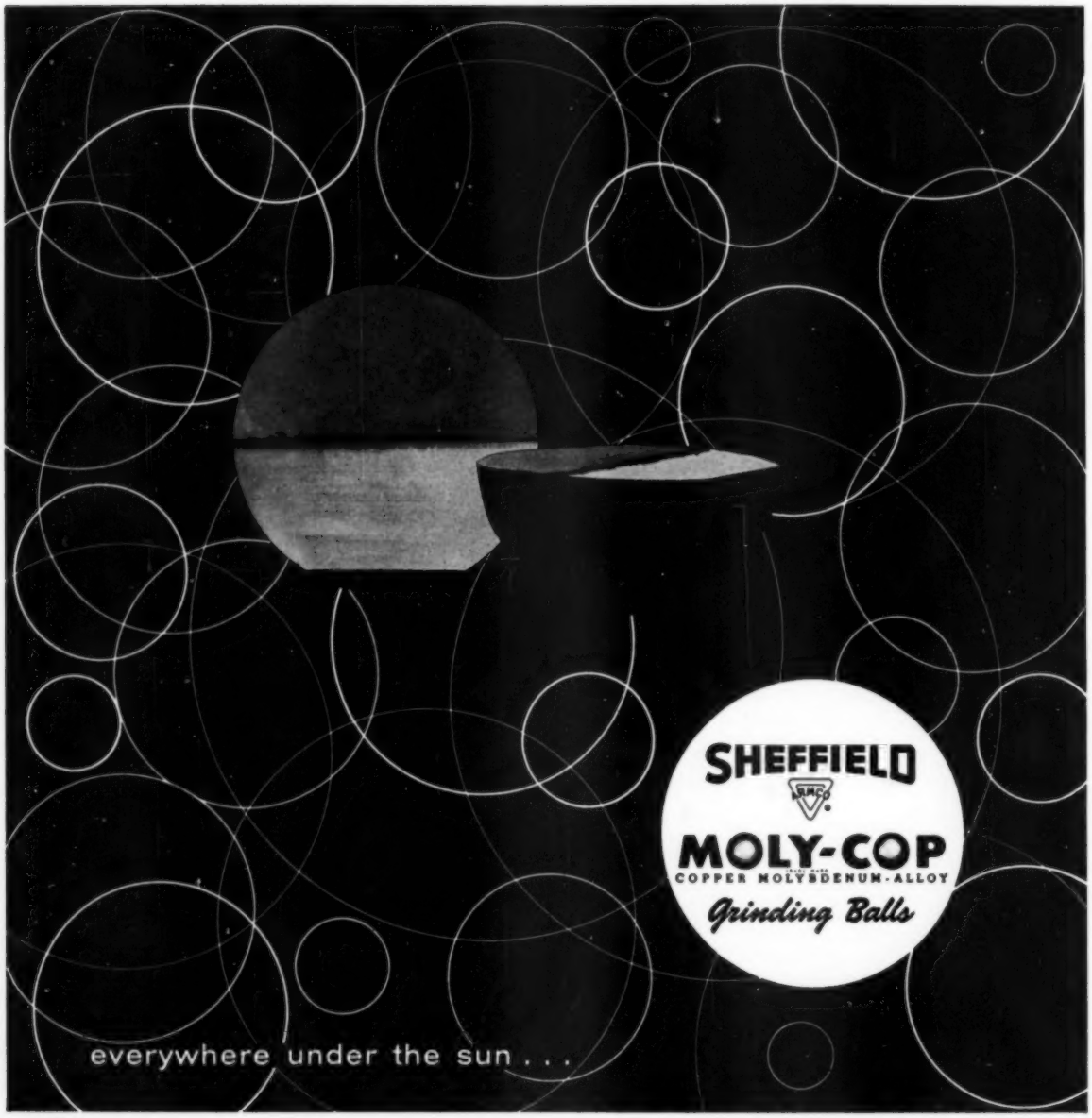

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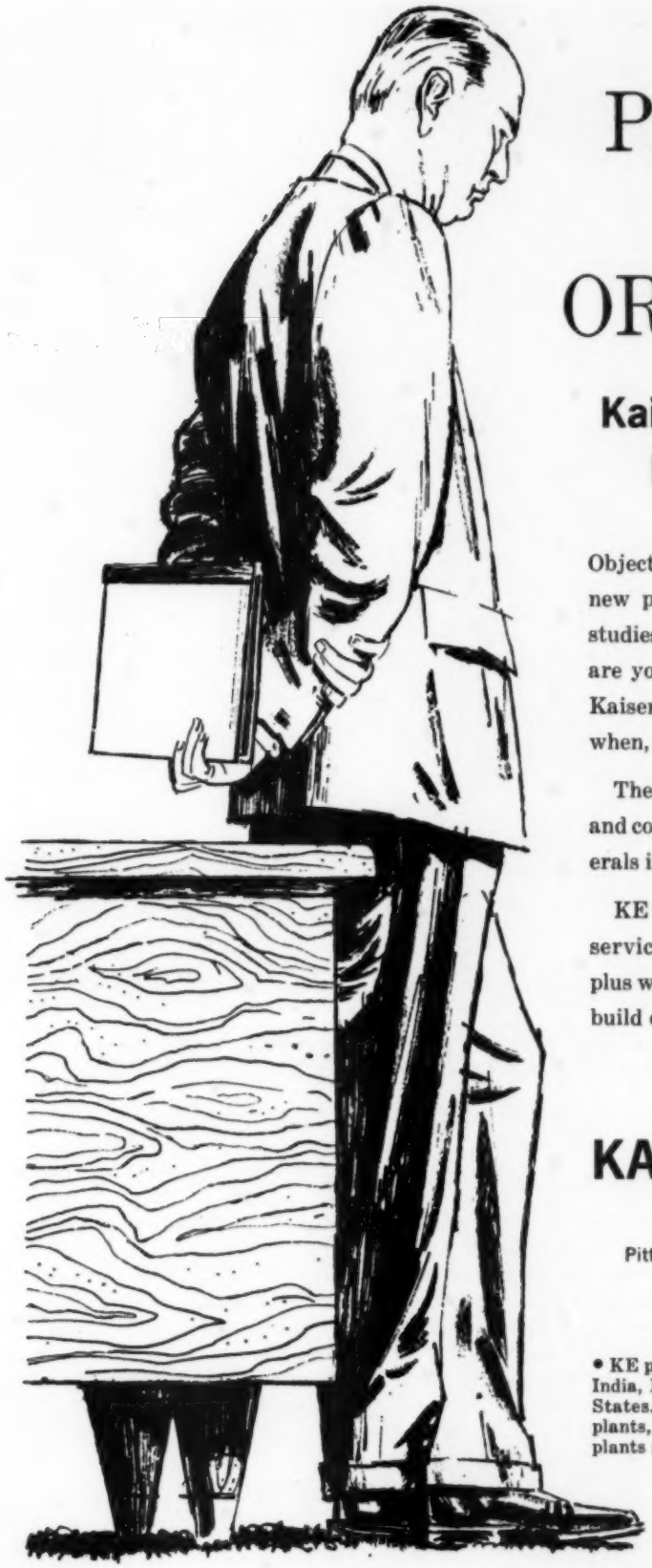

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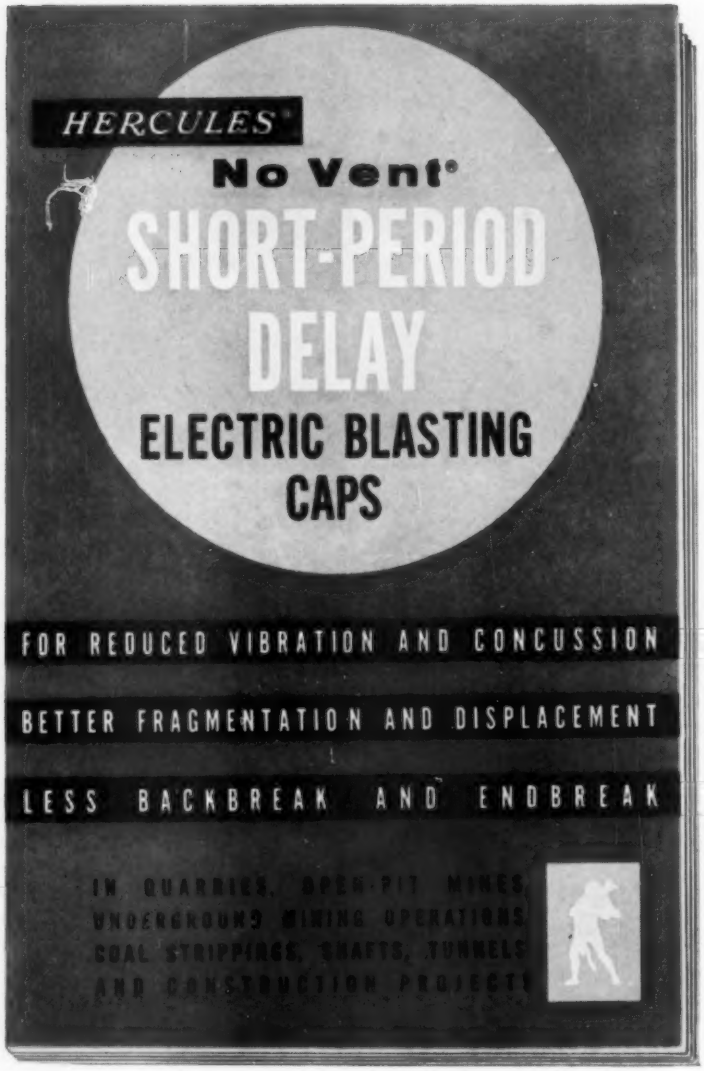

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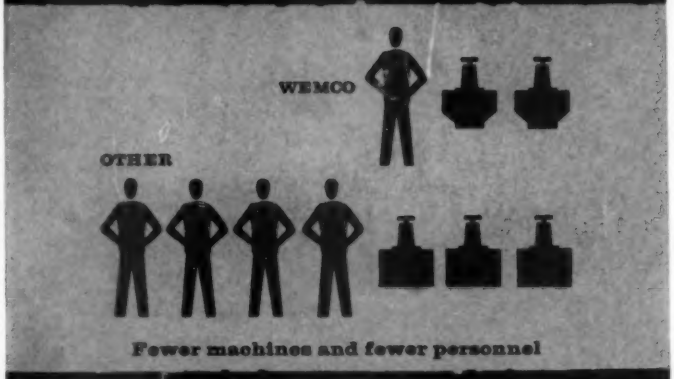
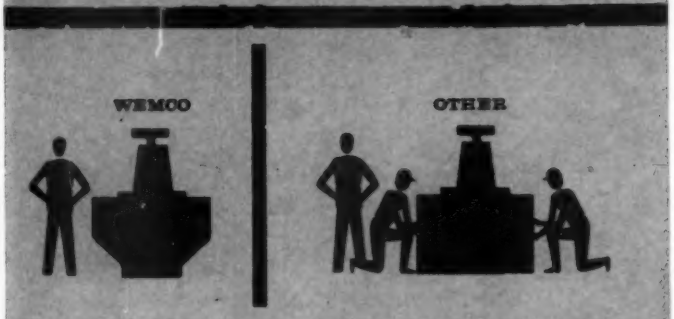


Fewer machines and fewer personnel



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MINING engineering **DRIFT**

REFERENCES: UNUSED RESOURCES

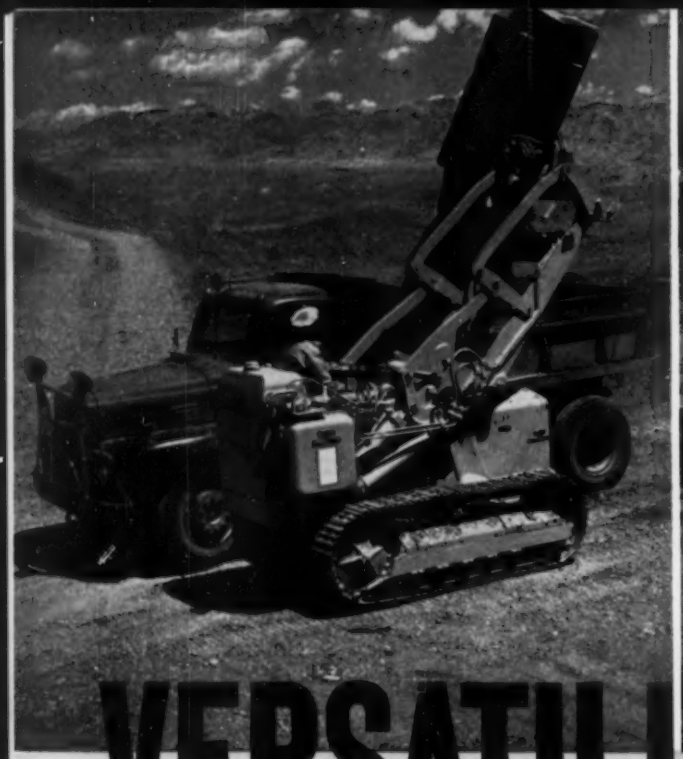
Before you read any further let me warn you that this is not about untapped *mineral* resources, nor is it about the more estoeric resources of library research. It is about some of the often overlooked common, garden variety references that should be available to any researcher or writer in the field.

• Especially now that it is on an accelerated publication schedule the *Minerals Yearbook*, prepared by the U. S. Bureau of Mines, is of great value as a basic source of data. A surprising percentage of the questions received by an organization like AIME can be answered from this volume, or by referring the person making the inquiry to the volume. The current 1957 Yearbook is in three volumes: (I) Metals and Minerals, (II) Fuels, and (III) Area Reports. Volume I is $3.50, Volume II is $2.25, and Volume III is $4.00 (These prices are for the bound 1957 edition.) Order from the Government Printing Office. The 1958 volume has already been largely issued in preprint form and should be available bound in the near future.

• We frequently get inquiries, find awkward word usages, or enlighten ourselves about strange terms through two volumes that do not seem to be as widely used as they should. For mining terms there is: *A Glossary of the Mining and Mineral Industry*, USBM Bulletin 95, $2.25. And for the field of geology there is: *Glossary of Geology and Related Sciences*, published by the American Geological Institute, Washington, D. C. The later of these volumes itself contains a two-page list of dictionaries and glossaries on geology and related fields.

• Some years ago MINING ENGINEERING had a copy editor with a fabulous knowledge of odd facts and information who made himself a lot of enemies. He did it rather simply. Quite often he would answer a question by asking if the questioner had checked in the dictionary. He usually had not, and more often than not the answer was there. This is my last unused resource: *Webster's New International Dictionary of the English Language* (usually known as the "unabridged").

These may seem like elementary recommendations for a researcher or writer's library, but fundamentals are often neglected. One could make many additions to this brief list; undoubtedly the volume AIME currently has at the printer, the third edition of *Industrial Minerals and Rocks*, should be one future addition.—*R. A. Beals*



VERSATILITY SPEED

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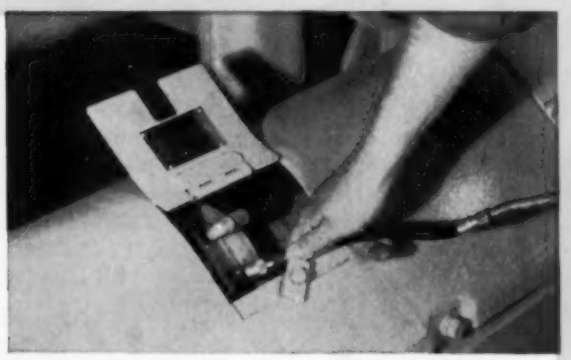

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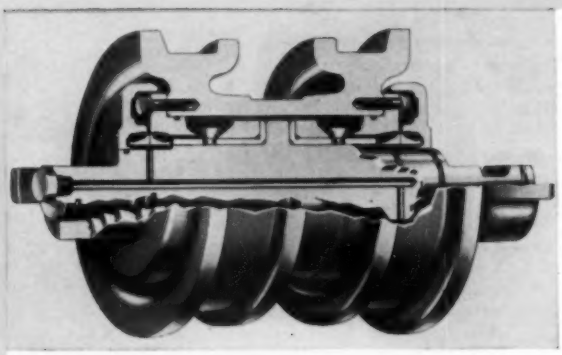

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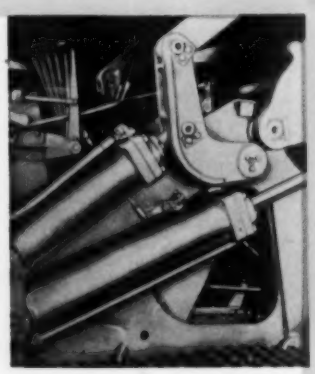

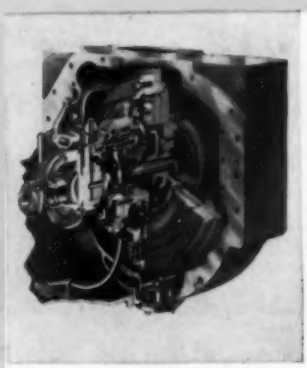

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WHATEVER THE JOB . . . whatever the conditions . . . there's a Caterpillar-built Traxcavator to take charge. Advance design has given this machine a reputation for speed . . . efficiency . . . low operating and maintenance costs. For this is a digging and loading tool; not a tractor attachment.

The line is complete. You get top production from three Traxcavators . . . the No. 933—52 HP, 1⅛ cu. yd. bucket; the No. 955—70 HP, 1½ cu. yd. bucket; the No. 977—100 HP, 2¼ cu. yd. bucket. And there's a complete range of quick-change attachments . . . special buckets, bulldozers, forks, the exclusive side dump bucket and the rear-mounted ripper.

Traxcavators are built to last. They have a heavy steel main frame, welded into a one-piece unit. Box construction track roller frame absorbs the loads and stresses of tough treatment. Lift arms are made to stand up under the strain of heaviest digging conditions.

Traxcavators give you fast action and ease of operation. Excellent stability and balance give better control of the machine. A fast hydraulic system cuts cycle time and increases maneuverability even in close quarters. Visibility is excellent. The high seat puts the operator on "top" of the work. Operator's compartment is uncluttered. Tractor controls are conveniently located for handling ease. Bucket controls are at the right armrest . . . closely spaced for dual operation with one hand.

The reliable Caterpillar Diesel Engine has a fuel-saving injection system and ability for hard lugging. Each engine is matched to the machine for power and bucket size.

All of these features pay off in top production. Let your Caterpillar Dealer help you choose the Traxcavator best suited for your job. Get production facts and figures. And ask for a demonstration.

Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

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BOOST PRODUCTION AND LOWER COSTS WITH A VERSATILE TRAXCAVATOR

AT BRADEN COPPER— SAFETY MEANS ECONOMY

by STANLEY M. JARRETT

Dramatic drop in Braden's total lost-time accidents, 1945 to 1957

Safe conditions and healthy environment increase the employe's job satisfaction and step up his efficiency. But only with training will employes accept safety as a responsibility and challenge. Here is Braden's safety organization and the results it has achieved.

Operating one of the world's largest underground copper mines, Braden Copper Co. has been able to reduce its total accident frequency rate per million manhours by 84 pct, from 27.4 pct in 1945 to 4.45 pct for the first ten months of 1958. It has also won the Inter-American Safety Trophy for 12 consecutive years.

The record may seem to indicate a secret formula, but there is none. The results stem only from hard work, and more and more of it.

Braden Copper, a subsidiary of Kennecott Copper Corp., is located on the western slopes of the Chilean Andes, some 45 miles southeast of Santiago. The mine, commonly called El Teniente, has an annual production capacity of about 10.9 million dry tons of ore. Mining is by progressive block-caving. Ore is dropped by gravity through a gathering-raise system to the lowest level, and is then transferred to electric ore-haulage trains and transported about two miles to the crushing plant.

SAFETY MEANS PROFIT

Braden proceeds on the basis that safety is a profitable investment and nothing short of the best is good enough. Not just a personnel problem, it also involves engineering, training, planning and production techniques, use of accident statistics, knowledge of compensation laws and procedures, and the ability to sell the program to all company personnel, to government agencies, and the public in general.

Accepting the view that accident prevention is basic in the productive process and can influence profit and loss, Braden found it logical to have the safety director report directly to the manager in charge of operations. Management, in its direct contact with the safety department, must provide the same kind of leadership and initiative it does elsewhere to reduce waste and produce economically.

Fire control, plant protection, and industrial hygiene are activities considered as part of the safety program. The department is consolidated and called the Safety and Industrial Hygiene Department.

ACCIDENTS

Prior to 1946 the frequency and severity of accidents at Braden was high. A survey revealed the following:

1) Working conditions were unsafe in some areas.
2) Supervisors of production and service de-

S. M. JARRETT is Director, Safety & Industrial Hygiene Dept., Braden Copper Co., Sewell, Chile.

partments were commonly inclined to view accidents as a natural though unfortunate byproduct of the industrial process.

3) The safety training program was inadequate to indoctrinate new personnel and instill a sense of responsibility and safety consciousness in supervisors and workers.
4) Safety personnel lacked authority.
5) The accident statistical system was inadequate.

Policies Changed: The following changes were made:

1) Management issued a statement of policy, setting forth the responsibilities and authority of the safety department and organized it as shown on the accompanying chart.

2) The accident statistical system was changed to conform to internationally-approved standards. Properly prepared and comprehensive accident statistics were recognized as fundamentally important in directing any efficient safety program.

The new statistics indicate graphically where, why, when, how, and to whom most accidents occur. With this information available, the safety director and supervisors are able to direct their efforts toward best results with a minimum of expense, time, and effort.

3) The supervisor's responsibility in accident prevention was clearly defined and emphasized. Assistance of supervisors and workers is encouraged by incentives and safety competitions.

4) Consolidation of related activities followed construction of a new centralized safety station and the centralization of the safety staff.

5) In close cooperation with the medical department, an adequate system of pre-employment examinations was instituted.

6) A properly planned safety training program was devised for all personnel, including:

a) Safety indoctrination courses for new men.
b) Modern first aid instruction available to all supervisors and workmen.
c) Special training courses for selected personnel on specific operations such as blasting techniques, fire control, etc.
d) Monthly safety meetings for supervisors and workmen.
e) Five-minute talks by supervisors to their men; on-the-job instruction by safety inspectors and supervisors.

7) Control of compliance with regulations was delegated to safety inspectors, who also oversee action taken on safety recommendations submitted to the various departments.

8) Routine physical checkup for all men engaged in transportation (cranemen, hoistmen, locomotive engineers, brakemen, drivers of motorized equipment, etc.)

9) General regulations were revised on safe operation and maintenance of all new equipment and machinery. Periodically, circulars are prepared and distributed for specific hazards and operations.

10) Safety suggestions are encouraged through incentives for ideas considered applicable.

Gratifying Results: The total accident frequency rate for the entire Braden operation in 1957 was 5.13 per million man-hours, while the cumulative factor as of August 31, 1958, was 4.45. According to recent statistics made available by the U.S. Bureau of Mines, the frequency rate for underground copper mines in the U.S. was 67.13 in 1955, and 66.89 in 1956. Underground mining operations at Braden for these two years indicate a frequency factor averaging 17.96.

Reduced accident frequencies have aided in improving productive efficiency, as shown in an accompanying graph.

All production levels operated consecutively from December 29, 1948, to September 7, 1955 (nearly seven years) without a fatality.

During 1952 and 1953, all departments of the company operated 494 consecutive days and 23,626,000 manhours of exposure without a fatality; 14,350,000 tons of ore were processed during the period.

Several departments and sections of the company have established records of over a million manhours without a lost-time accident.

Reduction of accidents has brought about considerable monetary savings as well as increased job efficiency.

SILICOSIS PROBLEM

All ore at Braden is won by a system of progressive block-caving. Extracted ore is transferred by gravity through a gathering system—the vertical distance ranging from 830 to 1660 ft—to the main haulage level for loading into electric trains. Ore transfer by gravity eliminates hoisting, as well as primary crushing, but the system is a serious dust producer and complicates the problem of ventilation. Drilling and blasting of about 3000 holes a day adds to the difficulty.

Size of the Problem: It was decided that radical measures were needed for a prompt and definite solution of the dust hazard.

First, employment and pre-occupational history of a group of 400 mine workers was screened. The

GENERAL MANAGER

SAFETY DIRECTOR

Industrial Hygiene	Plant Fire Control	Plant Inspections	Statistics, Training & Promotion
Ventilation and dust surveys	Inspection of fire hazards	Inspection of working places	Compilation and presentation of statistics
Use of micro-projection equipment	Maintenance of fire control and fire-fighting equipment	Field instruction to supervisors and workmen	Control of protective and first-aid materials
Control of dust-collecting systems	Employ fire brigades	Investigation of accidents	Safety posters, visual aids, and competitions
Maintenance of healthy environments	Training on fire control techniques	Control of compliance to laws and regulations	Mine rescue, first aid, and safety courses
Gas sampling and detection	Recommendations to improve hazardous conditions	Recommendations to correct hazardous conditions	Publication of bulletins, circulars, etc.
Recommendations to improve hazardous conditions			

men were then subjected to a rigid physical check-up and chest X-rays. The findings indicated that the men began to show evidence of the disease after seven to eight years of exposure.

A field survey was also needed to determine the magnitude of the existing hazard. The airborne dust was analyzed by the X-ray diffraction method to determine the free silica content in the -5μ portion. A program was then established to reduce dust concentrations in all work places below a maximum permissible limit of 5 million particles of -5μ free silica per cu ft of air.

Solutions: The following measures were put into effect:

1) The Industrial Hygiene section of the safety department was created. A dust and ventilation laboratory was installed and provided with microprojection equipment, dust sampling apparatus, and other related facilities.

2) The company established a total of 86 control stations where dust samples are taken at periodic intervals. Sites with dangerous concentrations are immediately surveyed for quick use of remedial measures.

3) Mechanically-controlled mine ventilation was installed, and new adits were driven to provide improved ventilation to all sections. Fresh air is drawn through the various portals and distributed to all underground workings by fans ranging in capacity from 175,000 to 50,000 cfm. As much as possible, the ventilation of each level is kept independent of others. All production areas have an independent supply of fresh air. Re-circulation of contaminated air is avoided by means of air-splits, ventilation doors, and auxiliary fans. Ventilation surveys are conducted monthly in all working areas.

4) The following measures were adopted to prevent dust dispersion from ore transfer and from blasting:

a) 100 pct wet drilling,
b) Wet-down of all working places and muck-piles before mucking,
c) Installation of air-water sprays in all development and undercutting operations. (Units are turned on before blasting.)
d) Blasting in development and undercutting operations at end of shift.

5) Ventilation and fire-control maps of all sections of the mine are kept up to date. The maps indicate velocities and direction of air currents by special color code, and show location of:

a) Dust and ventilation control stations
b) Fans
c) Ventilation and fire doors
d) Telephones
e) Refuge chambers
f) Fire-fighting equipment
g) Emergency exits from the mine

All supervisors are provided with pocket-size sets of maps.

6) An improved system of physical checkups for all new men is complemented by an accurate pre-employment history. During the first year this precluded the hiring of more than 50 workers suffering from varying stages of silicosis, silico-tuberculosis, and other pulmonary ailments.

A new X-ray machine was purchased to save time in mass examinations, and the discovery of disability cases through improved physicals resulted in savings which amounted to more than twice the total cost of the X-ray equipment. Yearly chest X-rays are now taken of all men exposed to dust hazards.

7) Dust collecting systems were designed and installed at all dusty operations—crushing plant, brick plant, silica crusher, etc. Engineering check-ups are made monthly to assure proper operating efficiency.

Results: During the 12 years that the prevention program has been in operation, no new cases of silicosis have been detected.

Success of program, in addition to the obvious benefits, has prevented the loss of many trained workers at a time when their job experience makes them most valuable. Another important benefit has been the improvement of human relations.

FIRE HAZARDS

The company property extends over a large area and the diversified operations include a wide variety of fire hazards.

In addition to the underground workings, processing plants, shops and foundries, storages and explosives magazines, there are hydroelectric plants, warehouses, yards, and lumber storages, railroads, offices, public buildings, and private dwellings.

While most of these potential fire hazards were being controlled fairly effectively, a preliminary survey indicated some hazards. The townsite, for instance, provides housing for more than 12,000 inhabitants who live in an area of 0.09 sq mile.

Fire control was the responsibility of various departments, and this resulted in duplication, overlapping and inefficiency. Moreover fire insurance premiums were high because of inadequate protection.

Methods: After a thorough survey, a number of steps were taken.

Underground Protection

1) A combination system is now used for warning underground personnel of an emergency. It consists of:

a) Stench (ethyl mercaptan) introduced in the main compressed air line feeding the entire mine.
b) A device which automatically flashed a warning by short flashes followed by long flashes indicating the level where the emergency has been reported.
c) Mine telephone switchboard operators also call the largest possible number of telephones, giving advice of the fire.

2) Mine Fire Procedure Instructions were developed with specific instructions for all personnel, including those of other departments.

3) Two or three practice drills, with complete evacuation of underground personnel, are carried out yearly. These drills point up any deficiencies in reporting system, evacuation, isolation of fire, etc.

4) Mine rescue instruction was organized. Rescue crews consist of about 60 specially-selected supervisors and workers. All members attend monthly classes on operation and maintenance of apparatus, detection of mine gases, fire control problems, simulated rescue operations, etc., and are paid a monthly bonus for their participation.

5) Concrete and steel sets were placed in the main adit, the power distribution access, to minimize fire hazard.

6) The mine was sectionalized by placing steel fire doors at strategic locations and around shaft stations, to permit prompt and effective isolation of a fire area.

7) All underground oil storages were constructed in raw-rock sections, protected with steel fire doors and equipped with suitable extinguishers.

8) Fireproof construction was used in underground offices, tool rooms, lamphouses, etc.

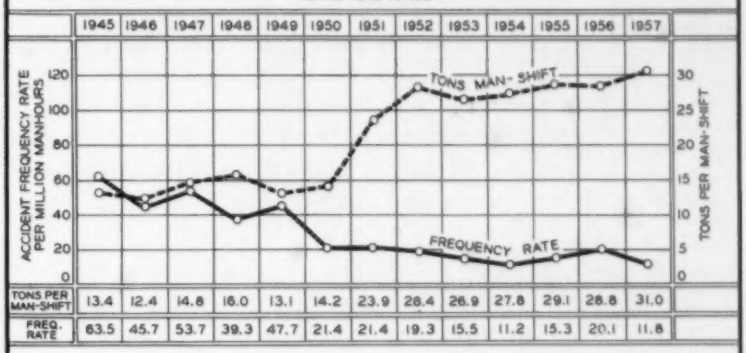
9) The underground electrical substation and power-distribution transformers were protected with automatic carbon-dioxide extinguishing systems. Pyranol was used in oil transformers.

10) A fire-control fan was installed at the lower haulage tunnel, one of the principal air intakes to the mine. The fan permits reversal of airflow between the portal and vital underground installations.

11) Routes to emergency exits were suitably indicated, and special emergency refuge chambers were built.

12) Improved fire-fighting equipment, consisting of fire hydrants and portable extinguishers, was installed at strategic spots.

BRADEN COPPER COMPANY
MINING DEPARTMENT
COMPARISON OF TONS PER MAN-SHIFT VERSUS ACCIDENT FREQUENCY RATE
YEARS 1945 TO 1957



	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
TONS PER MAN-SHIFT	13.4	12.4	14.8	16.0	13.1	14.2	23.9	28.4	26.9	27.8	29.1	28.8	31.0
FREQ. RATE	63.5	45.7	53.7	39.3	47.7	21.4	21.4	19.3	15.5	11.2	15.3	20.1	11.8

Plant Fire Protection

To improve fire control operations at the plant:

1) The Fire Control organization was consolidated under the safety department. The organization consists of a small nucleus of full-time firemen, complemented by volunteer fire brigades formed by personnel of the various departments in all camps of the property.

2) A thorough survey was made of all existing fire protection equipment, personnel, and fire hazards in all plant installations. Organization charts and control regulations were developed.

3) Fire control maps were prepared.

4) The various camps were divided into fire zones and a uniform system of alarm was established.

5) A system was instituted for periodic revision and recharging of extinguishers. Equipment was standardized.

6) Oil storage tanks were protected with foam generators. Automatic water and chemical sprinkler systems were used for protecting warehouses, shops, offices, residential quarters, etc.

TRAINING SAFETY MEN

Relatively few universities in the U.S. offer courses in safety engineering, although several have introduced post-graduate courses dealing with the essential principles of accident prevention and industrial hygiene. In general it is the responsibility of industry to train and develop its own safety engineers and technicians. Not all good engineers make good safety men, however.

Perhaps the following can be called the safety man's basic personal qualifications:

1) Ability to get along with people.
2) Enthusiasm, drive, perseverance.
3) Knowledge of engineering.
4) Capacity of analysis, deduction and discrimination.
5) Knowledge of human psychology and business administration.

While it may seem difficult to find a person with these qualifications, Braden has developed a long-range training program that is paying dividends: The company *graduates* its own safety technicians. Selected supervisors are put through an intensive course of training consisting of the following:

1) Accident statistics, and how to use them.
2) Fire control.
3) Ventilation and dust control.
4) Investigation of accidents.
5) Plant inspection aimed at preventing accidents and occupational diseases; accurate appraisal of existing problems.
6) Organization of safety committees, incentive systems, safety promotion.
7) Training personnel (safety orientation, first aid, and mine rescue courses).
8) Current legislation, processing of compensations, rehabilitation of disabled workers, proper job placement.
9) Safety control of men and equipment.
10) Report writing.
11) Human relations (personnel development, supervisory techniques, how to sell safety, how to control men, etc.)

This indoctrination course takes eight months to a year, after which the trainee is appointed safety inspector, in charge of a district. After a reasonable period, he is returned to his original department. He is then required to develop an appropriate training program for his subordinates and to work out the best compromise between production requirements and safety.

In this manner, the company is gradually developing a nucleus of supervisors who lend effective support to the overall safety program.

CONCLUSION

A man enjoying the benefits of modern techniques introduced for his protection and comfort not only works more efficiently, but also acquires a better standard of living. For his employer there will be no costly labor turnover and there will be minimum labor conflicts and dissatisfaction. Cost is returned many-fold by resulting savings.

DEVELOPING CHUQUICAMATA'S OPEN PIT HAULAGE SYSTEM

An efficient transportation system is a major factor in top mine output. Increased production demand in recent years has necessitated the improvement and expansion of the Chuquicamata system. Here is the story.

by ROBERT LAURICH

Chuquicamata pit was opened in 1915 with steam shovels and steam locomotives brought down from the Panama Canal excavation project. With expansions in the early years, more steam locomotives were brought into the mine.

IMPROVED LOCOMOTIVES

During the period 1927 to 1937, electric locomotives were purchased and main line and bench tracks were electrified. Third rail was installed up to the working areas. At first, the locomotives were equipped with batteries for service at the shovels, but charge life was too short and they were converted to use the third rail and a reel with 3000 ft of trailing cable for service in the loading area.

In 1950, five electric locomotives with diesel auxiliary motors were purchased. When used in the loading areas, these locomotives could service the shovels more rapidly than those using the cable reel and trailing cable. Because of the advantage of the combination, six electric locomotives were converted to use the diesel auxiliary. In 1956, steeper adverse grades forced a change to larger locomotives and diesel-electric units were brought into the mine.

Up to 1944, all ore haulage was downgrade to the level of the oxide plant crushing yard. Waste was dumped on or as close as possible to the level from which it was removed. In 1944, the first bench (F-4) below the level of the crushing yard, was developed, introducing the problem of hauling over adverse grades. Grades on the first track were held to a maximum 1.5 pct. A second track for empty trains and auxiliary equipment entered the bench at 3-pct grade.

Previous practice was to haul ten-car trains to the benches above the crushing yard, but the new 1.5-pct adverse grade made it necessary to use two locomotives (double-head) to pull 12-car trains from the lower benches. At this point production was not curtailed because haulage distances were short. The first three benches developed below crushing yard level were serviced in the same manner. To reach a dumping space to the east of the mine, waste removed from F-4 and benches below

R. LAURICH is General Mine Operations Foreman with Chile Exploration Co., Chuquicamata, Chile.

The Open Pit

The Chuquicamata ore deposit is one of the most valuable concentrations of copper ore known. The orebody extends north-south to a length of 10,000 ft and is of maximum width near the northern end, tapering south to a narrow wedge. The present pit follows the general configuration of the orebody and is 10,086 ft long, 3772 ft wide at its widest point and 1086 ft deep. Of the 23 benches opened to date, 21 are still active. Bench heights in the past varied in relation to the size and range of the development shovels used. Currently benches are being developed to a height of 52½ ft by an 11-cu yd shovel.

Current Production

Since the opening of the pit in 1915, 700 million tons of material have been removed, 472 million tons of ore and 228 million tons of waste. Present production, based on a six-day week, is 155,000 tpd, of which 42,500 tons is oxide ore, 48,000 tons sulfide ore, and 64,500 tons waste.

Mine Equipment

Equipment used to load and haul ore and waste includes 20 shovels. Thirteen are equipped with 4 and 4 ½-cu yd dippers, six with 6 ½-cu yd buckets and one development shovel is fitted with an 11-cu yd dipper. Of the 33 mine haulage locomotives, there are 14 600-hp to 752-hp electrics, 11 600-hp electrics with diesel auxiliary power, two 1200-hp diesel electrics, and five 1750-hp diesel electrics. Ore for the oxide plant crushers is hauled in 542 gondola-type cars of 70-ton capacity. Waste headed for the dumps, and sulfide ore going to the sulfide plant crushers, are hauled in 95 30-cu yd and 100 40-cu yd air-dump cars with downdrop side doors. Material from the upper levels of the mine is hauled by a fleet of 25 end-dump trucks including 5 30-ton, 12 25-ton, and eight 15-ton trucks. Auxiliary equipment working in conjunction with haulage equipment includes: three electric cranes and one diesel-electric locomotive crane, all of 50-ton capacity; nine bulldozers; three track shifters; four 40-cu yd ballast cars; one air-operated spreader plow; and two roadgraders.

Trackage

The railroad system has 80 miles of track, 48 miles of which are electrified with 650-v d-c rail. Trackage is U.S. Standard gage with 100-lb rail on main line track and 80-lb rail on bench tracks and waste dumps. Main line and dump tracks are laid with staggered joints. Bench track is laid in 39-ft panel sections, constructed and repaired in the mine salvage yard. Track on the waste dumps is moved by track shifters after the new trackbed has been prepared by an air-operated spreader plow. Bench track is laid or moved by 50-ton capacity locomotive cranes after the roadbed has been prepared by bulldozers.

Communication System

A chief dispatcher is in charge of all traffic movement. Traffic control is maintained by six dispatchers in charge of intermediate stations at strategic points in the mine. These dispatchers have control over electric switches located in their respective areas. Train movements are coordinated through telephone communication between stations.

Radio communication between the chief dispatcher and all locomotives and locomotive cranes was established in 1950. This close-knit communication system has speeded up train movements and re-routing of traffic when necessary.

is hauled to the crushing yard level and must cross the flow of ore traffic.

With the opening of the fourth and fifth benches below F-4 level, entrance track was brought in at 3-pct grade to keep within permanent slope lines.

In 1956, when the first 3-pct adverse grade entrance was constructed, diesel-electric locomotives of 1750 hp were introduced for the heavy haul. While 600-hp electric locomotives can pull only three-car trains out of these benches, the new diesel-electrics are capable of pulling nine-car trains. Standard practice is to double-head 18-car trains up to the 1.5 pct grade where one locomotive uncouples for further double-heading in the bottom benches.

The 1750-hp diesel electrics, when not used for pulling loads up the adverse grades, are used for hauling empty cars to the upper benches. Twenty-car trains are pulled up at higher speeds than the standard ten-car trains pulled by the electrics. Shovel loading efficiency has been increased by faster service and less switching. These large diesel-electrics are used exclusively for main line haulage.

Two 1200-hp diesel electric locomotives, brought to Chuquicamata in 1957, are used for switching cars in the benches and for main line haulage. In some areas, notably the sulfide zones, irregular bench grades created haulage problems for the 600-hp locomotives; the 1200-hp diesel electrics were needed for shovel service in these areas, to pull trains out to the passing track. This problem has now been eased by improved blasting practice, and the company is aiming at establishing level track in the benches.

Much thought has been given to increasing the number of 30 and 40-cu yd side dump cars per train—present practice is to use nine-car trains. Tests made with the 1200-hp diesel-electrics proved they can handle 15-car trains and still have sufficient compressor capacity to dump without loss of time. As more locomotives of this type are brought in, longer waste and sulfide-ore trains will be used.

TRUCK HAULAGE

A fleet of 25 end-dump trucks strips waste in the upper mine levels. The five 30-ton and 12 25-ton trucks are powered by 300-hp diesel engines and are equipped with torque converters. The eight 15-ton trucks have a standard transmission and are powered by 275-hp diesels. All the engines are equipped with superchargers and give very satisfactory service at the 9500-ft operating altitude. Removal of waste by truck haulage began in 1951; using nine vehicles, tonnage was 16,000 tons. Present daily tonnage averages 41,000 tons with 18 of the 25 trucks in service each shift. Average haul to waste dump is ⅝ mile.

Ore encountered in the trucking area is hauled to loading ramps and dumped into ore cars for rail transport to the crushers. Ore loading ramps are long enough for a train of ten cars and a locomotive is not needed at the ramp, except for switching empty and loaded trains. Average ore haul is a half mile.

RAILROAD SYSTEM EXPANSIONS

Expansion of the railroad system has progressed with the development of new benches. In the last fourteen years, or since the first bench was opened below the crushing yard level, expansion has centered on construction of new main line approaches down the ramps to the dropcuts made by the large development shovel.

In 1957, excavation for the construction of a new main-line approach to the west side of the mine began. Some 205,000 cu yd of fill were excavated to establish the roadbed, and 4800 ft of track were laid. The project was completed in 1959, making available more waste dumping space on the west

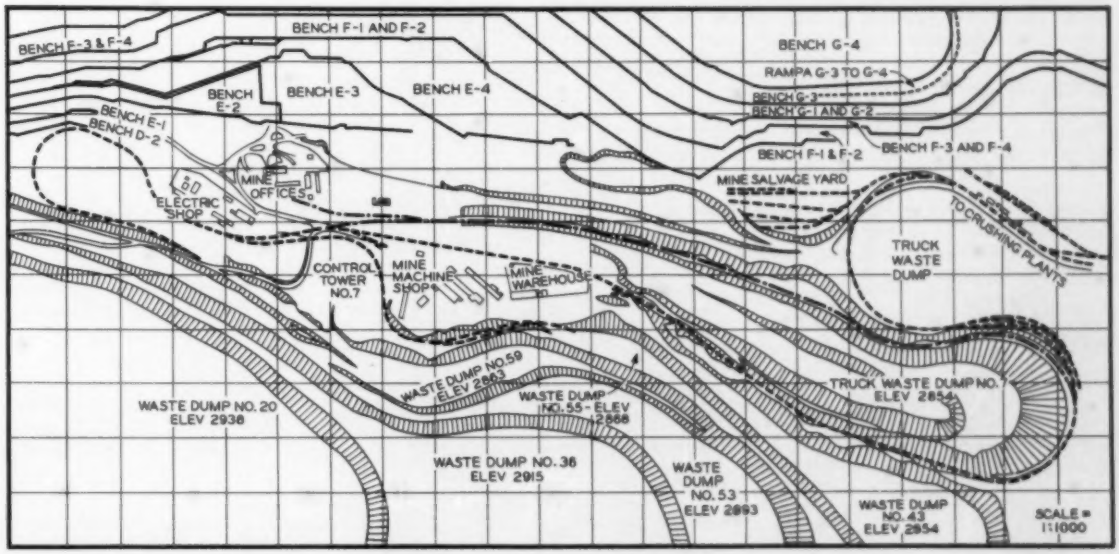


Fig. 1—Plan view of main line approach to west side of mine. Old loop track was dismantled to make room for 5 million tons of truck dumping space.

side of the mine. Capacity of this new truck dumping area is 5 million tons.

Hauling longer trains with 1750-hp locomotives has made it necessary to lengthen passing tracks near shovel areas to hold 20-car trains rather than former ten-car strings.

The heavier load put on trackage because of increased production has stepped up routine maintenance work and track standards are being raised. Heavier frogs are being installed in turnouts and a change from 100-lb to 132-lb rail on main-line track is contemplated. Track maintenance equipment is also being mechanized gradually. Better efficiency enables more frequent replacement of panel sections in the working areas and is raising the overall standard of bench track. Recent acquisition of four new 40-cu yd ballast cars with hydraulically-controlled spreader blades has made it possible to increase the amount of track ballasting. All bench track is now ballasted up to the loading areas and in some cases ballasting is being done in the loading areas themselves, especially in close curves. Increased maintenance and ballasting of track has decreased derailments of cars and locomotives by 40 pct, a factor which has helped greatly in maintaining the production level.

In 1953, construction of the new sulfide crushing plant southeast of the mine was completed. All ore to oxide and sulfide crushing plants and waste removed from F-4 and lower benches converge on one area, creating a bottleneck in the switching yard. Increased production had accentuated the tie-up problem.

A bypass of the congested area was begun in 1958 and completed January 1959. It involved construction of an underpass bridge and new main-line approach to the sulfide crushing plant. Flow of traffic to the waste dump east of the mine has also been diverted to this new mainline approach. This project involved relocation of 2800 ft of existing track and laying 5100 ft of new track. All work was carried out without interruption to existing traffic. The new mainline approach relieved pressure on the congested area and helped boost production by increasing haulage efficiency.

Direct shipment of sulfide ore to crushers was raised from an average of 35,000 tpd to 40,000 tpd. The consequence of this increase becomes apparent in reviewing past crushing practice. Chuqui's sulfide concentrator operates at a maximum capacity of 42,000 tpd, seven days a week. This requires a mine feed of 48,000 tons per working day. An additional 15,000 tons is loaded on Sundays, to make up for losses during the week. Since only 35,000 tpd was shipped directly to the sulfide crushers, the extra 13,000 tpd, necessary to keep the sulfide concentrator working at capacity, was sent to the oxide plant for crushing. Sulfide ore shipped to the oxide plant is crushed and loaded into leaching vats, and then removed by gantry bridges. These load side dump cars which carry the ore to the sulfide plant fine-ore storage bins. Crushing costs are higher than those of ore shipped directly to the sulfide crushers and the material occupied vat space which could have been used for oxide ore leaching. The new bypassing track permits direct shipping of an increased amount of ore and releases vat space for leaching more oxide ore.

FUTURE DEVELOPMENT

As the upper benches reach final slope lines and are retired, new benches are being developed in the pit floor.

Plans are being made to carry on a deep pit mining program, and haulage will depend on diesel-electric locomotives alone as the electric locomotives become obsolete. Each time a new bench is developed, more switchbacks become necessary to bring the ore trains from the deep levels to the crushing level. Future plans will have to take this into consideration.

Keeping abreast of new transportation developments assures the position of Chuquicamata, with its great reserves of ore, as one of the leading producers of copper for years to come.

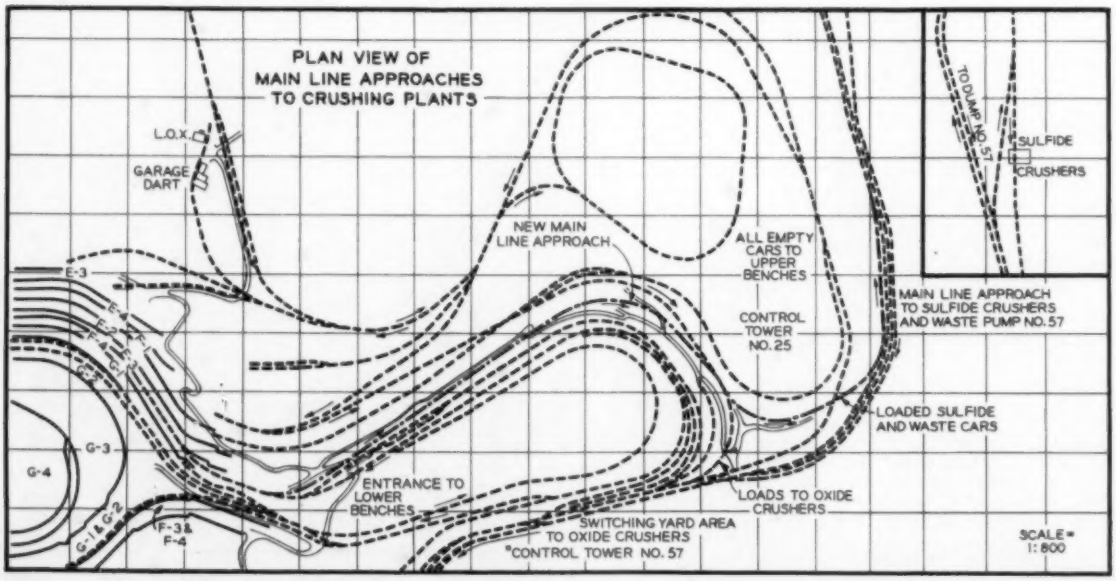


Fig. 2—Plan view of main line approaches to crushing plants, including new main line approach to sulfide crushers.

Paley Report Series—No. 4

FLUORSPAR AND THE INDUSTRIAL MINERALS

Another comparison of recent developments in the minerals industry and the 1952 findings of the President's Materials Policy Commission.

by RAYMOND B. LADOO

The Paley report made little attempt to project future production and consumption for any industrial mineral except fluorspar and only about a dozen minerals were mentioned by name. Except for fluorspar the treatment consisted mainly of statistics of production, consumption, imports, and sometimes reserves up to 1950.

FLUORSPAR

In 1954 the author had occasion to evaluate the Paley fluorspar estimates. At that time a fairly detailed study of the world picture was made and bases for the Paley estimates were studied. Data for later years confirm, in the main, the conclusions reached in this earlier report and it will be drawn upon here.

It is difficult to interpret and reconcile published figures on reserves, production, consumption, etc. because figures variously show short tons, metric tons, beneficiated spar as sold, and all forms of spar reduced to a 100-pct CaF_2 basis. For this reason statistics must be carefully interpreted.

Reserves: Table I shows the Paley table of world fluorspar reserves (Paley report, vol. II, p. 89, table II). U.S. reserves of fluorspar containing 35 pct or more CaF_2 are shown at 15 million short tons. Estimates of foreign reserves were *highly speculative*. In 1956 the U. S. Geological Survey published a new estimate of domestic fluorspar reserves of this grade, placing estimated reserves at about 22.5 million tons, of which 13.8 million were measured and indicated and 8.7 million tons inferred.[4] Added to this was 12 million tons of estimated ore grading 15 to 35 pct CaF_2. These increased estimates reflected, in part, much more detailed studies of previously known deposits and also new discoveries, especially in Illinois, Kentucky, Colorado, and Montana (Fig. 1).

The author knows of no very recent estimates of reserves in foreign countries, but heavy imports from Mexico, Italy, and Spain reveal strong activity in those countries. Mexico is the greatest enigma. It is known that there are very large reserves of fluorspar in Mexico but a search for comprehensive estimates proved fruitless. Mexican reserves are undoubtedly very much larger than the Paley estimate of 3 million gross tons. The U. S. imported well over 1 million tons of finished spar from Mexico in the period of 1954 to 1957 and imports are still holding up.*

* Since this was written, estimates of Mexican fluorspar reserves have been published by the U.S. Bureau of Mines, Mineral Trade Notes, Vol. 47, No. 6, Dec. 1958, p. 33.

Estimates of reserves rarely differentiate between ores which can yield coarse *gravel* grade spar for metallurgical use and those which must be concentrated by flotation and yield only finely-divided material of acid, ceramic, and glass grades. Until steel companies will accept pelletized spar this distinction is important. Many deposits, particularly those with siliceous gangue, will not economically yield metallurgical grade spar. It is often easier to make high grade acid spar than it is to make lower grade metallurgical spar. This problem led the Government to stockpile both types of spar, instead of only acid grade as at the start of its program.

Using the new estimates for U. S. spar adds 7.5 million tons to the Paley estimate. Doubling the estimate for Mexico adds another 3 million tons. A sheer guess of 2.5 million tons of new reserves for Europe and Southwest Africa will now bring the total to 53 million tons. Since these are for crude ore with 35 pct or more CaF_2, they must be reduced by some factor to arrive at shippable spar. Paley estimated that crude ore would yield 37 pct CaF_2. This is probably a fair figure for yield of all shippable spar, considering varying grades of crude spar and milling losses. Some 53 million tons of crude ore then would result in about 19.6 million tons of saleable product.

In the eight years of 1950 to 1957, world production as estimated by USBM was about 10.7 million tons. If consumption roughly equaled production then the assumed 19.6-million-ton reserve of shippable spar has, at the end of 1957, dropped to less than 9 million tons.

Since working out the above estimates the author has been able to check his opinions against those of an expert. Through the courtesy of Robert M. Grogan, Table II presents newly-estimated fluorspar reserves as they will appear in the 3rd ed. of AIME's *Industrial Minerals and Rocks*.* Grogan, in commenting on these estimates, says, "the author feels that Chermette's world reserve estimate of

* Ed.: Publication is scheduled for December 1959.

R. B. LADOO is an Independent Consulting Engineer, Newton, Mass.

Table I. Fluorspar Reserves of Free World, to 1950*

	Gross Weight, Millions of Tons	CaF_2 Content, Millions of Tons
United States	15	6
Canada (Newfoundland)	5	
West Germany	4	
Mexico	3	
Spain	3	
Others	10	8.8
Total	±40	±14.8

* Measured, indicated, and inferred ore containing 35 pct or more CaF_2 at 1951 prices. Data from USBM and USGS.

Table II. Order of Magnitude of World Reserves of Fluorspar Containing 35 Pct or More CaF_2

	Millions of Short Tons (references cited)			
	Hose[2]	Chermette[2]	U.S. Government[4]	Other
United States		11.0	22.6*	
Canada (incl. Newfoundland)		5.5		
Mexico		6.6		
Spain	3.3	6.6		2.2**
Germany, West	2.2	4.4		
Germany, East	1.1			
Italy	2.2	3.3		
United Kingdom	3.3	1.7		
France	1.1	1.7		
Other European	1.1	1.1		
USSR and satellites	5.5	8.8		
Africa, North		1.7		
Africa, South		1.7		
Other		1.1		
Total		55.2		

* Plus estimated 12 million short tons of low grade containing 15 to 34 pct CaF_2.
** Mineral Trade Notes, vol. 45, no. 3, p. 23, 1957.

Table III. U.S. Fluorspar Position in 1950 and Projected 1975

	Thousands of Tons, All Grades	
	1950	1975
Consumption	426	1150*
Production		
Natural fluorspar	275	300*
Phosphate rock	—	650**
Imports	165	200**

* Projected.
** Required.

Table IV. Fluorspar Position of Free World, in 1950 and Projected 1975, Excluding U.S.

	Thousands of Tons, All Grades	
	1950	1975
Consumption	175	640*
Production	325	840**
Exports to U.S.	165	200**

* Projected.
** Required.

55 million tons, made in 1953, is too low, and that 75 million tons would be closer to the mark at the present time."

Since 1953 the world has used at least 6 million tons. Grogan's estimate of 75 million tons of crude spar with 37 pct recovery would net less than 28 million tons of finished spar. Deducting the 6 million tons already used since 1953 we have 22 million tons, which, at the present world rate of consumption of over 1.5 million tons per year, gives us less than 15 years' supply. The Paley Report estimate for Free World consumption over the full period 1950 to 1957 averaged 1.2 million tons per year. Without knowing consumption of the Communist world it seems probable that in seven years the report's average has already been exceeded.

No matter how estimating is done—extrapolating from available published data—the conclusion seems inevitable that, unless very large new reserves are found or our rate of consumption declines, world fluorspar reserves will not be comfortably adequate. The present trend is toward higher consumption.

Consumption: Fig. 2 shows the USBM figures for domestic consumption of fluorspar from 1950 through 1957 and the Paley projection to 1.15 million tons in 1975. It will be noted that, except for the years 1954 and 1955, consumption has remained above the Paley trend lines; the 1954 steel strike sharply curtailed fluorspar consumption.

In 1950, U. S. consumption was about 426,000 short tons (58 pct metallurgical grade, 32 pct acid grade, and 10 pct ceramic grade). In 1957, total consumption had risen to a new high of nearly 645,000 tons. Of this total only 40 pct was metallurgical grade, 51 pct was acid grade, and 9 pct covered ceramics and miscellaneous uses. To be sure, 1957 was a year of reduced steel production but the trend was unmistakeable. The 1950 pattern was upset by the rapid rise in demand for hydrofluoric acid and its products. Some such increase was expected by the Paley report, which predicted a five-fold growth for aluminum industry use and a four-fold increase for chemical use by 1975.

No decline in consumption is indicated for any of the important uses. No substitute has been found for fluorspar in the steel industry and the amount used per ton of steel, while fluctuating from year to year, averages about what it was in 1950. Aluminum industry needs, per ton of aluminum, have not changed materially and aluminum production has continued its predicted rapid increase. Chemical uses continue to grow in kind and in volume. The Paley predictions on increasing rate of consumption were once considered by some observers as being too optimistic but so far they seem fairly accurate or even a bit pessimistic.

There are no good means of judging total world consumption except from production figures. Government stockpiling can be an influence, but stocks at mines and in the hands of consumers probably would not fluctuate enough to influence world-wide consumption figures.

As countries become more industrialized their use of fluorspar increases. The needs for acid spar in Europe may be expected to rise much faster than needs for metallurgical grade since European steelmaking methods consume much less fluorspar. Many European countries are now becoming important producers of chemicals, including those which need fluorspar, and Europe shortly may have no export-

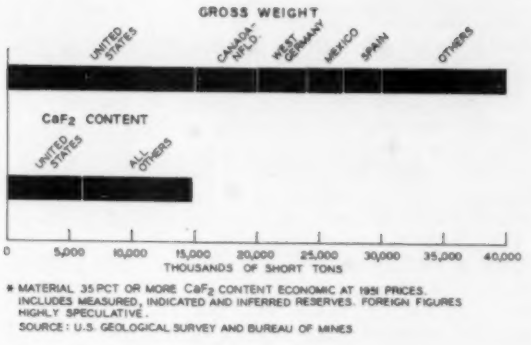


Fig. 1—Magnitude of fluorspar reserves in the free world.

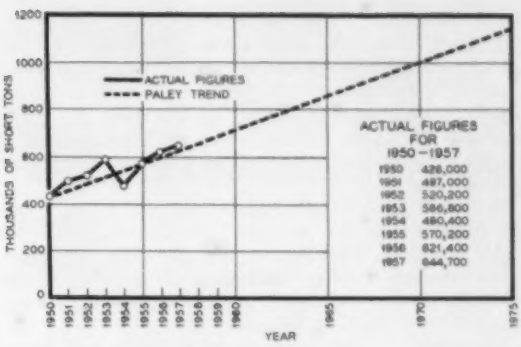


Fig. 2—U. S. Consumption of fluorspar, 1950-1957.

able surplus. For example, West Germany's estimated 2 million ton reserves would be exhausted in 10 years at its current rate of production.

Production: The Paley report concluded that, due to the downward trend in U.S. production, depletion of known very large deposits, and the unlikely discovery of other such large deposits in this country, the peak of domestic production had probably been passed by 1950. The actual peak came in 1944 at nearly 414,000 tons. In 1950 USBM reported shipments of 301,000 tons (the Paley Report showed only 275,000 tons). It stated that production of 300,000 tons per year might be expected by 1975. Actually production (shipments) varied from about 246,000 tons to 347,000 tons between 1950 and 1957. If U.S. reserves containing 35 pct or more CaF_2 now total 22.5 million tons, and 37 pct recovery may be expected, shippable spar reserves are 8.33 million tons. At an average annual production rate of 330,000 tons these reserves would last about 25 years. However, if the U.S. became wholly dependent on its own reserves, they would last only about 13 years at the 1957 rate of consumption.

Fluorine from Phosphate Rock: Aside from fluorspar the only known large and foreseeably commercial source of fluorine is phosphate rock. Natural cryolite production from Greenland is now too small to be an important factor. The Paley report rests its case for adequate fluorine supplies on large scale recovery from phosphate rock. Undoubtedly the fluorine is there. The weighted average fluorine content of domestic phosphate rock is 3.5 pct. In 1957 the 11.7 million tons consumed here contained nearly 410,000 tons of fluorine, equivalent to over 835,000 tons of pure CaF_2. If this had all been recovered in forms economically usable by industry there would have been no need to mine or import fluorspar. However, this was not the case.

In 1954 the author studied this situation in some detail and came to the conclusion that a number of factors militate against a large recovery of fluorine from phosphate rock:

1) More than a million tons per year are used as ground rock phosphate, without chemical treatment, chiefly for fertilizers.

2) By present treatment of phosphate rock by acidulation or by electrothermal processes, only a fraction of the contained fluorine is evolved. The fraction usually varies from 25 to 35 pct and reaches a maximum of 42 pct in a few cases. No weighted average is available but it may be as high as 30 pct. Hill and Jacob,[5] in their estimate of total evolved fluorine in the 1950 production of superphosphate, phosphoric acid, and phosphorus, indicate a weighted average of only about 27.7 pct. In order to increase the percentage of evolution it is probable that major changes in plants and processes would have to be made, calling for large capital investments.

3) Not all of the evolved fluorine is collected or collectable under present or foreseeable conditions. In 1950 not over a sixth of total fluorine evolved was actually recovered. The following quotations from Hill and Jacob give some of the reasons for this situation. "The low score on the recovery of evolved fluorine is attributable, generally, to an unfavorable distribution of evolution and lack of incentive for recovery . . . . The pre-eminent position of ordinary superphosphate, tonnagewise, in the phosphate processing industries and the rather high percentage volatilization give this manufacture first place as regards fluorine evolution." (Superphosphate production in 1952 used 57 pct of the total rock sold or used by producers; in 1956, 36 pct.) But in 1951 this production was distributed over 204 plants in 32 states. About 53 pct came from 156 plants with annual capacities of under 100,000 tons each. The fluorine content of the rock used by the average plant in this group was only about 930 tons, of which 29 pct or 270 tons was the estimated evolution. This small average per plant accounts for lack of interest in this group. Hill and Jacob point out, "Only 19 recovery units were coexistent with the ordinary superphosphate plants in 1951," of which five were idle. This same picture prevails in other types of phosphate rock processing. "At the present time the cost of recovery would often exceed the market value of the product," they conclude.

The small size of many processing plants, the cost of recovery equipment and of production, the relatively low recoveries possible in present processes, all are factors against profitable commercial fluorine recovery from this source.

4) In such fluorine recovery plants as existed in 1952 (except for one experimental pilot plant) the products were largely fluosilic acid and its salts.

Some of this was sold for making sodium fluoride but most of it was sold as fluosilicates. In 1950 perhaps 14,000 tons of fluorine were recovered commercially, mostly by large corporations. Fluosilicates, the easiest form of fluorine recovery products to make, do not make economically good starting points for making either calcium fluoride or hydrofluoric acid.

Hill and Jacob believed best markets for byproduct fluosilicates lay in the fluoridation of public water supplies. For this rapidly growing use, fluorine chemicals (sodium silicofluoride and fluosilicic acid) can be made without first extracting pure fluorine from the byproducts.

The Paley report took a much more optimistic view of this situation but dismissed too lightly the process and production difficulties and the economic problems. At some price and scarcity level, it undoubtedly would pay phosphate fertilizer producers to make necessary capital investments to increase evolution, to recover evolved fluorine, and to convert to calcium fluoride and hydrofluoric acid. But fluorspar reserves must first become more nearly exhausted and prices must rise considerably.

Today the greatly increased drive against air pollution has given impetus to the collection of evolved fluorine, particularly in the larger plants. Agricultural trends toward higher analysis fertilizers and increased chemical uses have stimulated the construction of new plants to produce phosphates for fertilizer and for industrial use by new and improved processes.

Much work has been done and is planned on the problem of increasing fluorine recovery from phosphate rock in forms suitable for commercial use. Processes have been developed for making synthetic cryolite for the aluminum industry direct from byproduct fluorine compounds after phosphate rock processing. One aluminum company has signed a five-year contract for 10,000 tons per year from this source.

The Paley report visualized 50 pct recovery of fluorine content of the phosphate rock used in 1975. In 1950, total evolution averaged only 27.7 pct, of which only 1/6, or 4.6 pct, was actually recovered. It is difficult to believe that this 4.6 pct recovery will increase to 50 pct by 1975.

The potentialities of phosphate rock as our ultimate source of fluorine have received much study and the consensus is that even though recovery of fluorine will continue to increase and form an important part of supply, it will not be a major source until or unless fluorspar prices increase greatly.

World Situation in 1975: The Paley report attempted to project the world picture of fluorspar production and consumption in 1975.[1] The following tables are adapted from the report.

The Paley report expressed the belief that, by the means indicated in Table III, our supply and demand picture would be in balance in 1975. In this opinion there are several weaknesses in that reasoning.

1) It is doubtful that domestic production can hold to the level of 300,000 tons per year until 1975.

2) Without great increases in prices it is unlikely that fluorine recovery from phosphate rock, in a form acceptable to most users, will reach the equivalent of 650,000 tons of fluorspar by 1975.

3) With presently known deposits it is questionable if foreign countries can or will be willing to export to us as much as 200,000 tons per year by 1975.

Beyond 1975 the report seems to assume that fluorine recovery from phosphate rock will not only keep pace with increasing fluorspar demand but will also make up for deficits from declining production and imports. It says that if recovery from phosphate rock does not reach projected levels by 1975 "imports would have to much larger." But there is no suggestion as to where such imports might come from.

As shown in Table IV, the report projected greatly increased consumption in foreign countries and a production increase of over 2½ times to cover increased use at home, plus 200,000 tons annually for export to the U. S. Again the report fails to suggest the source of this production, except to say that foreign producers of phosphate rock will also recover large tonnages of fluorine.

Combining Tables III and IV, we get an estimated total 1975 Free World consumption of 1.79 million tons per year of all grades, 1.14 million tons from natural fluorspar and 650,000 tons (fluorspar equivalent) from phosphate rock. World production in 1956 and 1957 averaged over 1.78 million tons. Thus world output has already reached the report's projected 1975 Free World consumption, and fluorine recovery from phosphate rock remains insignificant.

Certain conclusions must be made: 1) the search for new reserves outside this country must be intensified, 2) capacities of foreign plants must be increased and new plants built, and 3) rapid progress must be made in increasing fluorine recovery from phosphate rock.

If we are not successful in these endeavors, consumption cannot increase at the projected rate.

ASBESTOS

Average domestic consumption of all grades of absestos for the 1946 to 1949 period was about 572,000 short tons. The Paley report visualized an increase of about 50 pct by 1975, or a growth rate of 2 pct per year. On this basis the 1957 consumption might have been expected to be about 14 pct above the 1946 to 1949 average and this would result in a figure of about 652,000 tons. Actually consumption was 723,492 tons, which was close to that of 1954 and 1956. The use in 1955 was still higher, with over 782,000 tons. From these figures it would appear that the Paley estimates were far too low. However, in the same sentence which included the 50 pct projected increase is the statement that the demand for short fiber grades might be "some 1 million tons" in 1975. This would imply a growth of around 75 pct in 25 years or 5 pct a year, or 35 pct in seven years. Applying this rate to the 1946 to 1949 base derives a figure of 772,200 tons for 1957, which is a little higher than actual.

Since Paley figures are internally incompatible no conclusions can be reached.

The situation of asbestos reserves has not changed in kind although it has changed in degree. The U. S. is still very far from being able to supply its own needs. No very large new high grade asbestos deposits have been discovered. Less than 8 pct (by value) of the asbestos used in this country in 1957 came from domestic sources. Of the 92 pct imported, Canada supplied about 77 pct and Africa about 12.5 pct.

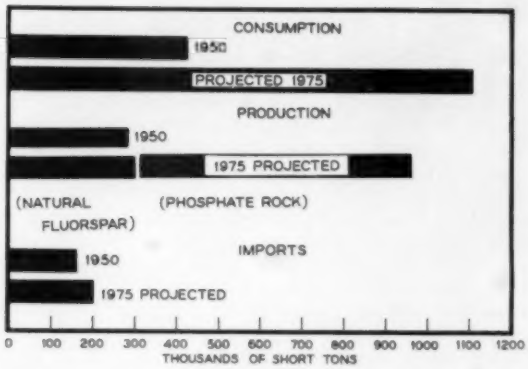


Fig. 3—U. S. fluorspar position in 1950 and projected for 1975.

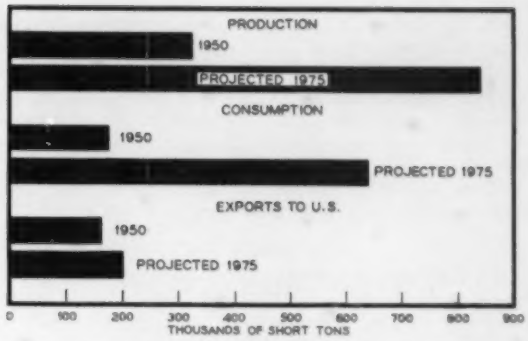


Fig. 4—Free World (excluding U. S.) fluorspar position in 1950 and projected for 1975.

Important new additions have been made to reserves in British Columbia, Ontario, Quebec, Newfoundland, and elsewhere.

Improved glass fibers have made inroads into some asbestos markets but they are not yet economic or technical substitutes for most uses. Synthetic asbestos has not yet been achieved.

Productive capacity has increased very greatly. Large new mills have put present capacity much in excess of market needs. Some observers believe it will take many years for demand to catch up but optimistic producers think the situation will be balanced in a very few years.

BARITE

The Paley report had little to say about barite and its information was inexpert. It stated, "Supplies of barite are plentiful. No new uses are on the horizon and no phenomenal growth in demand need be expected until research uncovers more unusual properties." Actually demand, as evidenced by domestic producers' sales, increased 2½ times from the 1947 to 1951 average sales of around 600,000 tons to 1956 sales of over 1.5 million tons. This would certainly indicate phenomenal growth.

INDUSTRIAL DIAMONDS

Consumption of industrial diamonds is a fairly good index of U. S. mechanical production. The Paley report, in fact, ties its projection of industrial diamond consumption in 1975 to the projected production of steel ingots in that year. U. S. consumption in 1950 was around 12 million carats and the projected consumption in 1975 was 20 million carats. Thus the estimated growth rate was 8 million carats in 25 years or 0.32 carats per year. For the six years 1950 to 1956, the estimated increase would then be 1.9 million carats or 13.9 million carats for 1956. The actual 1956 consumption was 16.1 million carats and the 1953 to 1956 growth was at a fairly steady rate. The actual growth rate then for 1950 through 1956 was more than 0.68 carats per year or more than twice the rate estimated by Paley. If this growth rate holds until 1975, the consumption would be 29 million carats for that year.

Paley estimated that annual consumption for the rest of the Free World by 1975 would be about 14 million carats. This would result in total Free World consumption of 41 million carats in 1975, compared with the Paley estimate of 34 million carats. This estimate for the rest of the Free World seems high. In recent years U. S. consumption has been about 85 pct of reported total world production. Assuming that over the years production equals consumption, then consumption of the rest of the Free World has been about 17.6 pct of that of the U. S. If domestic consumption in 1975 is estimated at 29 million carats and consumption of the rest of the Free World is 17.6 pct of that, the Paley report figure should be 5.1 million carats for 1975 instead of the actually estimated 14 million carats. The total would then become 34 million carats for 1975 instead of 41 million. Curiously enough, 34 million carats is the total Free World figure for 1975 reached by the Paley Commission using entirely different figures.

The report's estimate for total world reserves of industrial diamonds, probably too low, was 580 million carats, of which 300 million was in the Belgian Congo. Taking an average annual Free World consumption of 25 million carats for 25 years (1950 to 1975) arrives at total needs for this period of 625 million carats, or far more than the 1950 estimate of world reserves. This does not necessarily mean that world reserves of industrial diamonds will be exhausted by 1975. But it does mean that the indicated rate of increase cannot continue until 1975 (based wholly on natural diamonds) unless actual reserves are greater than those estimated by Paley.

So far we have considered only the Free World. But Russia and its satellites have large and growing needs for industrial diamonds and they have not been self-sufficient. However, Russia now claims to have found large reserves, enough for Communist World needs and perhaps some surplus for export. It has been reported that in recent years Russia has obtained large quantities of diamonds by smuggling through neutral countries.

It is well known that the U. S. has no commercial diamond deposits. The country is entirely dependent on imports and has built or is still building an important stockpile. But strenuous efforts are being made to reduce dependence on imported natural diamonds. These efforts may be summarized briefly:

1) Improvement and greater use of hard metal alloys such as tungsten carbide.

2) More efficient use of industrial diamonds.

3) More efficient methods for reclaiming used diamonds and diamond dust.

4) Development of new ultra-hard substances such as boron nitride and boron carbide.

5) Manufacture of synthetic diamonds. It is well known that General Electric Co. can now make industrial diamonds. They are now being sold commercially and are reported to be as efficient as natural diamonds. Cost is still a little high and production is small compared with needs, but the important thing is that they can be made.

MICA

Mica at best is a complicated problem. The mineral is used in so many different sizes and qualities for such varying purposes that generalizations are difficult. The two most essential types are clear sheet muscovite mica for electrical capacitors and thin splittings of muscovite or phlogopite for making built-up mica. These two essential categories of mica, particularly capacitor mica, were very scarce during World War II and the Government still is stockpiling both under subsidized prices. Reserves and production in these categories have been entirely adequate for domestic needs. Great efforts are being made to free the U. S. from dependence on imported mica. The Paley Commission believed so firmly that the problem would be solved by 1975 that the report stated, "For this reason no attempt is made at estimating future levels of mica consumption, or the ability of the free world to meet such demands from reserves of *strategic* mica."

While the problem has not yet been solved, many developments have lessened the need for strategic mica in many applications. Among these are the following:

1) Electric circuits and equipment designed to use less mica and in smaller sizes or to do without it entirely.

2) Commercial development of bonded mica sheets in continuous strips, made up from flakes of mica ¼ in. or smaller.

3) Commercial development of synthetic mica. Clear flat crystals suitable for sheeting into thin plates have not yet been made commercially, but material of superior quality suitable for grinding and rebonding with glass or other binders into solid shapes is now being successfully marketed.

4) Finely ground, high grade natural mica is now bonded with binders of superior electrical and physical properties to make plates, sheets, and solid shapes.

5) Greatly improved synthetic resins are now available, suitable for bonding mica, for insulating varnishes, and for potting small electrical units. These resins have much higher resistance to heat and moisture, are tougher and more flexible, and have greatly improved electrical qualities. Their use may reduce or, in some cases, obviate the use of mica.

6) Improved electrical ceramics.

The U. S. is largely dependent on imported mica for the most essential uses. In spite of very active search for new deposits during two world wars and Government-subsidized mica buying during and since World War II, our reserve situation is still wholly inadequate. There seems to be little or no prospect that we can produce large quantities of strategic mica.

Lower grades of sheet mica for less critical uses and grades suitable for making ground mica present no problems except those of cost of production.

PHOSPHATE ROCK

The Paley report did not present a detailed summary of present or future conditions in the phosphate rock industry. It did state that "known domestic deposits of phosphate that are mineable under present economic conditions represent a supply for more than 1300 years at the current rate of consumption." It also stated that domestic consumption for all uses might be expected to double by 1975. Domestic phosphate rock consumption in 1950 was about 8.6 million tons. Thus 1975 consumption might be expected to be around 17 million tons. The expected annual rate of increase would be around 344,000 tons per year. The expected 1957 consumption would then be about 11 million tons. Consumption was actually about 11.7 million tons, much like 1956. Projected consumption as of 1957 was therefore about right.

Perhaps fortunately, the commission attempted no projection of crude phosphate rock production. Due to increasing use of western rock, which averages lower grade than Florida rock, and to the mining of progressively lower grades of Florida rock, mined tonnages of crude have increased faster than consumption of up-graded rock.

POTASH

No shortage of potash was visualized in the foreseeable future and indeed there is no shortage. The Paley report estimated that world "reserves in the deposits presently being mined . . . are more than 5 billion tons of K_2O, which would be sufficient to last for more than 1000 years at the 1949 production rate of about 3.5 million tons." Since then new production has come into being in New Mexico, where there are now six producers, and an important new field in Saskatchewan is being rapidly developed.

Domestic potash use has expanded from about 1.1 million tons in the 1949 to 1950 fertilizer year to about 1.9 million tons at present. Total U. S. use of complete fertilizers has expanded 60 pct in the same period. Thus, while consumption has increased spectacularly, new reserves give assurance that there will be no shortages for many years.

QUARTZ CRYSTALS

This country has never produced any significant amount of clear crystal quartz of electronic grade. All must be imported, chiefly from Brazil, but in part from Madagascar. U. S. consumption of piezo-electric grade quartz in the 1947 to 1951 period averaged about 114,500 lb per year out of total imports of around 576,000 lb of all electronic and optical grade crude quartz. In addition there were large imports of *lascar* or clear quartz of non-electronic grade used for making clear fused quartz. Peak consumption of electronic grade quartz was about 2 million lb in 1944. In 1952 a sub-peak of 502,500 lb was reached. Then consumption declined, but in 1957 again reached a total of about 167,000 lb out of a 432,000-lb total of imported high grade crude. In addition, about 1.1 million lb of lascar were imported in 1957. A Government stockpile, built up after the war, was completed in 1957.

Improved technology of quartz cutting and use of smaller units has more than doubled the number of piezo-electric units which can be cut from a pound of raw quartz. While piezo-electric units for

oscillator plates accounted for about 91 pct of production in 1957, there was an accelerated demand for large crystals for making crystal filters for long-distance automatic-dialing telephone circuits.

There has been great activity in growing synthetic quartz crystals of piezo-electric quality. Such crystals can now be grown by several methods. Costs are still considerably higher than for natural quartz of equal size but some types are reported to have a usability of four to five times that of natural quartz.

Paley report expectations of economic as well as technical success for synthetic quartz three to five years after 1950 have not quite been realized. However, we seem to be well on the road to independence of foreign sources for piezo-electric quartz. But that does not solve the problem of a supply of lascar for clear fused quartz. Lascar now sells for 50¢ to $1 per lb, compared with electronic grades at $12 to $40 per lb and more.

SULFUR

The Paley report on sulfur was content with a summary of 1950 conditions and the general conclusion that the yellow mineral is primarily an economic problem. Estimates of world reserves were given in the form of a native sulfur, pyrite, metalliferous ores, and metal smelter fumes. The very large reserves of native sulfur in Mexico had not been proven and extensive recovery of sulfur from petroleum and natural gas had not been realized. These latter sources were briefly mentioned as ultimate possibilities but their near-term utilization was apparently not expected.

Air and water pollution problems have greatly hastened the recovery of byproduct sulfur. In 1956 the recovery of elemental sulfur from petroleum and natural gas had increased more than four-fold from the 1947 to 1951 average, and the recovery of byproduct sulfuric acid from smelters increased about 70 pct over the same period. Meanwhile Frasch process sulfur recovery increased only about 30 pct.

Large new Mexican production and the greatly increased recovery from other sources have had great effects on world as well as domestic markets, to the detriment of Frasch process producers in this country.

The sulfur problem remains, now as in 1950, primarily economic.

OTHER INDUSTRIAL MINERALS

Other industrial minerals and mineral products mentioned by the report include agricultural raw materials in general, glass, cement and concrete, clay and shale. The treatment was so general that for present purposes little can be deduced from it.

Considerable space was given to titanium but it was mostly concerned with the metal. The few comments on titanium dioxide pigments were largely technological and dealt mostly with the status quo rather than with the future.

The treatment given boron, beryllium, zirconium, thorium, and the rare earths was similar to that given to titanium. Little in it specifically concerned the industrial mineral field.

Conclusion: A study of the Paley report leads to the conclusion that, on the whole, an incomplete and spotty job was done on the industrial minerals. A lack of familiarity with the full facts was indicated even in the fairly close study of fluorspar.

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MINING LAWS OF MEXICO

by LUIS G. GUTIERREZ and AGUSTIN S. SEGURA

Foreign investment in Mexico, particularly of American capital, has increased steadily since 1940. At present, however, these investments are less important to the Mexican economy than in earlier periods. In the last few years, local or Mexican capital has participated in most American investments in Mexico with the encouragement of the Mexican Government.

Foreign investment in a wide variety of industrial activities has gone up in the last decade, placing mining investments in second place. This growth is the result of the Mexican Government's favorable attitude toward industrial expansion. The process has been encouraged through tax exemption on infant industry, through customs protection, and through other incentives.

As a result of the fast growth of general industry, Mexican mining has been declining in relative importance except for coal and petroleum. However, between 3 and 4 pct of the national income is produced by the industry and, in spite of production declines in the last few years, mining continues to be a very important source of both revenue and foreign exchange. In exports mining production represents a third of annual value.

Most Mexican mining output is exported in the form of refined metals, impure bars, concentrates, and ores. In 1953, approximately 90 pct of the total

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value of mineral and metal production was exported. The total 1953 mining production was valued at 2.196 billion pesos, of which exports were valued at 1.78 billion pesos. Of all Mexican mineral exports, the U. S. purchased 80 pct.

Foreign investments in Mexico depend largely on the official attitude and administrative decisions of the Mexican Government. The official position has been stated at several international conferences, principally at the Ninth International Conference of American States held in Bogota, Colombia, in 1948. Later, at the Third Extraordinary Meeting of the Inter-American Economic and Social Council held in Caracas, Venezuela, in February, 1953, official views were given as follows:

"The financing of the economic development of Mexico is based chiefly on domestic resources, although this does not mean that foreign capital may not play a supplementary role . . . Mexico believes that, in order to insure a more rapid and sustained economic development, the flow of foreign investment should be relatively stable and contribute to increasing the capacity to meet obligations abroad."

In conclusion, Mexico welcomes foreign capital which agrees to "accept an equal treatment under Mexican law as domestic capital." On the whole, the official attitude has been favorable to foreign investment in recent years, although in certain circles of the government there are sporadic cases of opposition. Sections of the industry also sometimes assume an antagonistic feeling toward foreign investment, especially in times of financial crisis.

According to the Mexican Constitution of 1917, the country is declared owner of "all minerals or substances which form deposits of a nature distinct from the earth itself, and also of almost all surface and subsurface waters." This has been the traditional policy of the Mexican governments, which have claimed that Mexico as a nation inherited the rights of the Spanish crown on the subsoil or underground. This system of national ownership of the mineral rights is essentially different from the American concept of private ownership, in which the owner of the surface land is also the owner of the minerals found underneath. In short, Mexican law declares that a person who owns a piece of land does not necessarily have the right to exploit its minerals, inasmuch as the government may grant a mining concession to someone else.

Another striking difference between Mexican and American mining laws is that U. S. mining concessions are granted for a full deposit, as in a vein, where the claim holder has the right to the full extent of the orebody, whereas in Mexico concessions are granted for a definite number of surface hectares (*pertenencias*), the claim holder's rights extending only as far as the vertical downward projection of the surface claim limits.

The Mexican Constitution also provides, in Article 27, that aliens, as well as Mexicans, have the right to obtain concessions for working mineral deposits (except petroleum, which is closed to both Mexicans and foreigners by the establishment of a government monopoly) or to utilize the waters in the Republic. However, as a condition for exercising this right, aliens must agree to abide by the laws of Mexico and to waive diplomatic intervention in disputes which might arise under such concessions. Furthermore, the Mexican Constitution provides that foreigners cannot own land or water within 100 km of the border-lines, or 50 km inland from the coast. Mining can be conducted by foreign-owned Mexican companies and all Mexican companies receive equal treatment, whether foreign or Mexican-owned.

Enforcement of mining legislation and granting of concessions in Mexico are functions of the Ministry of Economy (Secretaria de la Economia Nacional) through its Bureau of Mines and Petroleum. The basic principles, as already pointed out, are established by the Constitution of 1917, and by the Mining Law of 1930 and its regulations, as amended subsequently.

TYPES OF MINING CONCESSIONS

There exist in Mexico three different types of mining concessions: 1) Cateo (exploration), 2) Exploitation, and 3) metallurgical plant concessions.

Although the Mexican Mining Law establishes (Article 6) that only Mexicans have the right to obtain mining concessions, it also states that aliens can obtain such concessions if they comply with Article 27 of the Constitution, as mentioned above. This does not apply to foreign governments or societies.

NATIONAL MINING RESERVES

In an effort to control and regulate the production of some minerals, their deposits have been declared national reserves. The reserves are divided as follows:

1) Substances
2) Zones
3) Placer deposits

In the first case the reserves comprise all the national deposits of the subject mineral. In the second, only certain areas are declared reserves. In the last group, all placer deposits are included. Besides such placer deposits the reserves include all iron deposits (excluding the ochres), sulfur deposits associated with salt domes, and all radioactive minerals.

Concessions Possible: It is possible to obtain mining concessions for minerals included in the National Reserves in two forms:

1) Exploitation concessions by zones:

Concessions by zones are for those gold or tin placers where no special equipment is needed. They are only granted to a single individual, who must be a Mexican, and they cannot be transferred to a third person. They carry no time limit, but the holder must present himself before the local Mining Agent once a year.

2) Exploitation concessions by the hectare:

Concessions by the hectare comprise placers which require special mining equipment and deposits other than placers. They are granted only to Mexican individuals or organizations and are transferable to other Mexican citizens or firms after at least two years of actual mining. These concessions carry the same rights as those of ordinary Exploitation claims. A royalty of 3 pct of the value of total production from the claims must be paid to the Federal Government through the Comision de Fomento Minero. Mining can be stopped if it does not pay, provided previous notice is given to the Ministry of Economy.

Special Regulations: Other rules apply as follows:

1) Iron deposits—Special concessions for mining iron ore reserves are given in accordance with the technical and economical capacity of the applicant and intended end use of the ore. The ore must be

processed in the claim holder's own treatment plant within the Mexican Republic. The holder is obliged to supply ore to other consumers in the country if they do not possess their own sources, provided he has a surplus after discounting 20-year reserves. No concessions are granted to plants that already have a sufficient source of supply.

These concessions are ususally given for two periods: a) two years for exploration, and b) the time required for mining, as specified below. The applicant must show that he is proceeding with appropriate technical advice and has enough capital for exploration and mining. The concessions extend up to 30 years, at the end of which an additional 20-year period can be secured. The minimum concessible area is 20 hectares; the maximum is 500 hectares, either in one single claim or in several claims in different parts of the country.

2) Sulfur deposits associated with salt domes—The same regulations apply to these as in the case of other reserves, the concessions permitting one year of exploration before actual mining. The concessible area is that associated with the entire salt dome. A 4-pct royalty on the total value of production must be paid directly to the Federal Government.

3) Radioactive mineral deposits—Deposits of this type are not concessible. Notwithstanding, a contract with the National Commission of Nuclear Energy can be obtained for prospecting and mining. The contract will stipulate its effective term and the payment to be received by the operator in return for his work and amortization of his capital investment. It is understood that total production is the property of the country and output must go to the National Commission of Nuclear Energy. All contracts must be approved by the President of the Republic.

Other: It is worth noting here that rocks in general are held to belong to the landowners and are not concessible at all, unless they are in some way useful for the mining or petroleum industries. Products of rock alteration or weathering, such as kaolin, clays, and sands belong in this group, but they are concessible if exploitation requires underground methods. In this case concessions must be applied for under the rules for nonmetallics.

Mine dumps within the limits of a concession belong to the claimholder, unless they are derived from workings outside his claim.

MINING INDUSTRY TAXES

The mining industry is exempted from direct state and municipal taxes but direct Federal taxes are applied at the rate of $15 pesos per hectare per year. Only 50 pct of this sum, however, is actually charged during the first five years of the concession. Production taxes are payable whether the enterprise has been favorable or not. Other taxes include the ad valorem export tax, sampling, and assaying taxes.

The production and ad valorem export taxes are the most important charges, representing, for example, a rough 31 pct of copper market prices.

Mexico's mining taxation is fundamentally designed to favor processing minerals within the country. Thus, the tax schedule on production is lower for refined bars than for impure bars and is lower for impure bars than for ore concentrates.

The sum of normal income tax, distributable profit tax, excess profit tax, plus the other taxes mentioned above, surpasses the 52 pct rate for U. S. corporations. For this reason, Mexican taxes cannot be said to be among the lowest in Latin America.

But, despite the tax situation, there are positive factors which favor foreign investment in Mexico, particularly from the U. S. Among such advantages are the following:

1) Mexico's adjacency to the U. S.
2) Large, relatively unexplored areas where there is little or no competition.
3) Extensive commercial relations between Mexico and the U. S.
4) Availability of American-type equipment.
5) Low wage costs.
6) Reduction of import duties on mine equipment by special permits from the Federal Government.

The primary condition for obtaining a mining concession of any kind is that the claimed area be free; if any prior claims have been staked, they should be obsolete by the date of the new claim. If two or more claims cover the same area, the first one registered has primacy. If registering were done at exactly the same time, the registrants draw lots for primacy. The first step will then be to register the claims at the local Mining Agency (54 agencies are located throughout the country). Once the claim has been accepted, an officially-registered surveyor must do the actual measuring and staking. These data must be turned in at the Mining Agency where the claim was first registered within the next 60 workdays or the claim is considered invalid.

Exploration: The main characteristics of the Cateo claim are as follows:

1) Area of the claim is 9 hectares (about 22 acres) in a square 300 m to the side.
2) Immediate exploitation can be permitted by the local Mining Agent after the special work of the surveyor has been turned in. No claim monuments are necessary.
3) The claim lasts only two years and is not renewable.
4) At the end of the two-year period the Cateo claim must be changed to an Exploitation claim if the holder wants to keep concession.
5) Any person is entitled to only one Cateo concession.

Exploitation: In the Exploitation concession, minerals have been divided into three groups:

1) Metallic minerals,
2) Nonmetallic minerals, including guano and amber,
3) Coal and graphite.

Any exploitation can only include the minerals of a single group.

Exploitation concessions are granted for unlimited periods and encompass a maximum area of 100 hectares (about 250 acres), but in the case of coal they can be of as much as 1000 hectares. Any person may have more than one concession of this kind. The holder is entitled to set up processing plants as convenient or necessary. Claim monuments must be built so that adjacent markers can be seen on each side.

Assessment work must be reported yearly to the Mexican Bureau of Mines and Petroleum, although only 50 pct of this work must be proved completed (in the form of salaries paid to laborers). Prospecting and/or sampling are not considered assessment work.

If in the course of exploitation a new mineral is discovered which is not included in the group for which the concession was granted, a special permit for mining the new mineral must be secured from the Ministry of Economy.

Exploitation concessions will be annulled in the following cases: 1) lack of deficiency of assessment work after the first three years of the concession, and 2) failure to pay surface taxes. In both cases the claim-holder will be granted additional time, on application.

Any titled mining concession can be rented, sold or optioned to a third person. To make such a transaction legal it must be duly registered at the Public Mining Registry of the Ministry of Economy in Mexico City.

Metallurgical Plants: The owner of any mining concession has the right to expropriate the necessary amount of land within or outside the limits of his claim site for such purposes as building access roads, stockyards, pipelines, powerlines for his own use, metallurgical or processing plants, and any other installation he may find fit or necessary for proper hauling and preparation of its minerals products. The expropriation should be done under the control of the Ministry of Economy and the affected land owner will be paid a fair compensation. Alien claim holders can only proceed with expropriation after showing that they have complied with Article 27 of the Mexican Constitution.

Concessions for processing plants are of two kinds:

1) Private service
2) Public service

The first can only be granted to exploitation claimholders, in which case they are compelled to set aside at least 20 pct of their capacity for custom processing, if and when the custom ores are amenable to treatment by the available plant facilities. Custom processing is invariably done on the basis of first come, first served. No concession is required for processing plants of capacity smaller than 25 tpd, if intended for private use by a claimholder. Plants cannot be dismantled totally or in part unless granted a permit by the Ministry of Economy. Such a permit is also necessary for any changes in plant capacity. A plant of this kind will lose its concession when it unjustifiably refuses to receive custom ores.

Applications: Applications for mining concessions shall have the following data:

1) Name of applicant, whether one individual or an organization.
2) Type of concession desired.
3) Location, stating municipality and state.
4) Substances to be mined.
5) Name of claim.
6) Starting point for measurements.
7) Site of neighboring claims, including their names.
8) Statement that the area applied for has or has not been staked before, naming holders of previous concessions.

MINING SUBSIDIES

In an effort to encourage mining enterprises, the Mexican Government in 1955 passed a law establishing diverse subsidies applicable to small or medium-scale operations. Special agreements also can be secured for large-scale operators.

The subsidies amount to the net Federal revenue derived from the mining and metallurgical operations affected by the following taxes:

a) Taxes on the production of minerals, metals, and metallic compounds.
b) Export taxes applicable to the above materials.

The subsidies constitute a percentage, as follows:

a) Up to a 75-pct tax reduction for those enterprises paying up to $25,000 pesos per month as combined production-export taxes.
b) When the basic tax is higher than $25,000 pesos per month, the subsidy will be reduced, on a sliding scale, to nothing for these companies that pay taxes of $250,000 pesos per month.

When a producer owns two mining units operating separately from each other he may be entitled to a separate subsidy in each of them. This type of subsidy is only applicable to mine producers. It is by no means extended to buyers or custom mills of metals, minerals, or metallic compounds. It is also not applicable to persons mining iron ores, coal, graphite, fluorite, or quicksilver.

The Ministry of Revenue can sign fiscal agreements with large scale operators to assist in:

1) Low grade mining.
2) Maintaining important mining activities for social welfare.
3) Mining orebodies that for natural reasons generate high costs.
4) Important exploration projects in mines with low reserves or in important mining districts.
5) Faster amortization of invested capital to open up or reopen a new or non-producing mine where large investments are required.
6) Renewing operating equipment when owners cannot afford to.
7) Constructing new mine roads.
8) Installing new metallurgical plants or substantially renovating existing ones.
9) Developing mining and metallurgical activities that could supply necessary and/or scarce materials.
10) Treating slags, dumps, and tailings.
11) Compensating operating losses of efficient enterprises.
12) Securing reasonable profit when the operators are unable to, in spite of high mining efficiency.

Besides the already listed subsidies, exemptions are granted to enterprises that begin operations in new mines or in old mines that for some reason have not been operated for the last ten years. These exemptions apply as follows:

1) Reduction of 50 pct on the first two years of operation.
2) Reduction of 30 pct during the third and fourth years.
3) Reduction of 10 pct during the fifth year.

Although the law on subsidies and fiscal agreements came into effect on January 1, 1956, agreements have been signed or are about to be signed which will promote the investment of an estimated $700 million pesos.

The Mexican Government endeavors to steadily improve the country's taxation laws so that, in the near future, systematic exploration and exploitation of mineral resources can be undertaken.

PEBBLE MILLING PRACTICE AT THE SOUTH AFRICAN GOLD MINES OF UNION CORP. LTD.

by O. A. E. JACKSON

Pebble milling has been practiced in the reduction works of South Africa gold mines for well over 50 years. Originally flint pebbles were imported from Denmark to grind stamp-mill amalgamation-process tailing, which contained a good deal of extractable gold, but local operators soon found that large pieces of ore could be used for the same purpose.

The ore is a hard, tough conglomerate in which quartz pebbles are cemented together by a matrix of redeposited silica interspersed with pyrite crystals. The gold, rarely visible, occurs as fine particles mostly segregated at the interface of the pebble and matrix, although a small fraction occurs within the pyrite crystals. There is seldom any gold in the pebbles themselves.

Following the usual South African practice in pebble milling, Union Corp. grinds the ore wet in two or three milling stages incorporating classification. The sized broken ore used as grinding media is separated from the main ore stream in the crushing section that prepares the ore for milling.

Where the ore channel, or *reef*, is narrow there is a shortage of large pebbles. In this case primary grinding may be done in ball mills or, more recently, in rod mills, which cost less per ton to operate. The trend, however, is to prepare finer feed for the milling section. This makes it possible to use smaller primary pebbles and eliminates the need for steel.

REDUCTION WORKS OF UNION CORP. LTD.

Union Corp. Ltd. exercises financial and technical control over a group of seven gold mines in the Transvaal and Orange Free State. In the Transvaal, with one exception. the mines lie 20 to 40 miles east of Johannesburg, in flat or gently rolling countryside. Winkelhaak, the first of several new mines that will be developed by Union Corp., is located in similar terrain in an entirely new gold mining district about 80 miles east of Johannesburg.

Table I gives details of milling units for six of the Union Corp. mines, together with the tonnage milled in 1957. Winkelhaak Mines Ltd. is not included, as it did not begin milling until 1958. This reduction plant has no crushing section; ore is ground directly from the mine (autogenously) in 12x16-ft mills. Because these operations are still in development, they are not described in this article.

It will be noted that certain reduction works have mills of more than one size in the same milling stage. This came about when plant extensions incorporated larger units. In the case of Geduld Propty. Mines Ltd., which began milling operations 50 years ago, the primary stage is stamp milling.

The reduction works follow a uniform pattern and are usually joined to the main ore shaft. Ore from other shafts is brought by standard-gage railway and dumped into a common transfer bin. The trend is to increase surface storage capacity to enable the crushing and milling sections to operate at a steady rate, independent of fluctuating ore deliveries from mine.

Milling and cyanide extraction divisions of new mines are always designed to allow for extensions as mine production increases. The conveying, washing, and screening system of the crushing section is usually laid out in final form, with additional space for more crushing equipment. The crushing sections operate on one shift during early years of mine production; a second shift is introduced when the mining rate warrants it. Ample surge capacity is provided.

Crushing and milling is done only on weekdays, as the law does not allow these operations to take place on Sunday in any plants constructed since 1911. The cyanide extraction sections, however, operate continuously seven days a week, drawing on mill pulp gradually built up in the thickeners during the week.

Construction and equipment of milling plants follow standard practice. Dilution water is drawn from a large, high-level tank to obtain constant pressure, but gland service water for the pulp pumps is reticulated from high-pressure, two-stage pumps.

The mills are equipped with the most up-to-date machinery and are designed to save labor. They compare favorably with milling plants in countries where native labor does not exist, and automatic controls are being installed wherever feasible.

Hydrocyclone classifiers have replaced mechanical classifiers in modern milling plants, chiefly because of the saving in capital outlay, maintenance, and building space. The hydroclones are fed from steady head boxes rather than directly from pumps, and dilution water is introduced into these boxes. Tests have shown that in steadiness of operation and separating efficiency cyclones are comparable to mechanical classifiers, but protective stationary screens are needed to keep the spigots clear.

Rubber-lined pumps are used for pulp of about 3 mesh or finer and metal-lined pumps for coarser material.

None of the Union Corp. milling plants practices gravity concentration of coarse gold by amalgamation or the use of corduroy blankets. Studies have proved that no economic case can be made for these methods, which complicate the milling process and demand extra precautions against theft.

O. A. E. JACKSON is Consulting Metallurgist, Union Corp. Ltd., Springs, Transvaal, South Africa. TP 5987. Manuscript, Nov. 10, 1958. San Francisco Meeting, February 1959. AIME Trans., Vol. 214, 1959.

Feed Preparation and Pebble Production: Mill feed is prepared in the crushing section. Here the ore is washed to permit waste-sorting; pebbles of suitable sizes are separated for the various milling stages; and the remainder is crushed, in conjunction with closed-circuit screening, to the desired size as primary mill feed.

After going through a jaw crusher, the incoming ore is washed and sized as it passes over grizzlies and vibrating screens. The washings are classified, thickened, and pumped to the milling section to join the feed to the secondary circuit. Native sorters pick off waste quartzite and shale down to about 3-in. size, usually from two conveyor belts moving at 80 fpm. They average 10 tons per native-shift, sorting out roughly 10 pct from run-of-mine ore received.

Although primary pebbles are sorted by hand at present, in any new reduction works they will be separated by vibrating grizzlies or vibrating screens. Secondary and tertiary pebbles are separated by stationary grizzlies or by vibrating screens. Pebbles are transported to individual mill bins by 1-ton mine cars on an endless rope haulage system in the older plants and by conveyor belts, over weightometers, in the newer ones. The rest of the ore, usually about 80 pct of the crushing section feed, is crushed in two stages by both standard and shorthead Symons crushers in closed circuit with vibrating screens. The modern trend is to crush to about 95 pct $-\frac{3}{8}$ in., but some plants are not equipped to crush as fine as this. The crushed ore is carried by conveyor belts to mill bins of rather more than one day's milling capacity.

Slow-moving conveyor belts under the bins receive the crushed ore from chutes having adjustable gates and thence travel over weightometers and under the primary pebble bins, delivering their loads directly into the mill feed hoppers.

Feeding the relatively small proportion of pebbles into these hoppers from the storage bins has created problems in design. Among the devices currently in use are ratchet-driven conveyor belts, pan feeders, vibrating feeders, or roll feeders. In an 8x16-ft mill the pebble consumption, depending on prevailing conditions, is equivalent to a 1 to 3-in. load shrinkage per hr at the axis. The aim is to feed as continuously as possible. Guided by a meter on the control panel, the mill operator adds enough pebbles to maintain the power drawn by the mill motor at a maximum. The modern practice, however, is to employ vibrating feeders, which will be operated by the Williamson electronic automatic pebble feed controller recently developed and patented by Union Corp. Ltd.

Description of Mills: In recent years the size and speed of pebble mills has been increased. In reduction works constructed before 1930, 5½x22-ft and 6½x20-ft mills were installed. In the following decade four new reduction works were built containing 8x16-ft pebble mills. In 1948 two 21x16-ft pebble mills were installed as a self-contained unit to extend the reduction works at Grootvlei. These have proved very satisfactory, being cheaper in capital cost per ton of −200 mesh produced. Ten such mills have now been installed in reduction works of the Union Corp. group.

A number of mill drive installations have reverted to the spur gear and pinion system, with a reduction gear interposed between the driving motor and pinion shaft. Three large reduction works built in the late 1930's contain 8x12-ft mills driven by the center-drive principle: a torsion shaft fitted to a double-reduction gear box is coupled directly to a specially designed discharge trunnion. This system has operated satisfactorily but is more expensive to install than the conventional spur gear and pinion system.

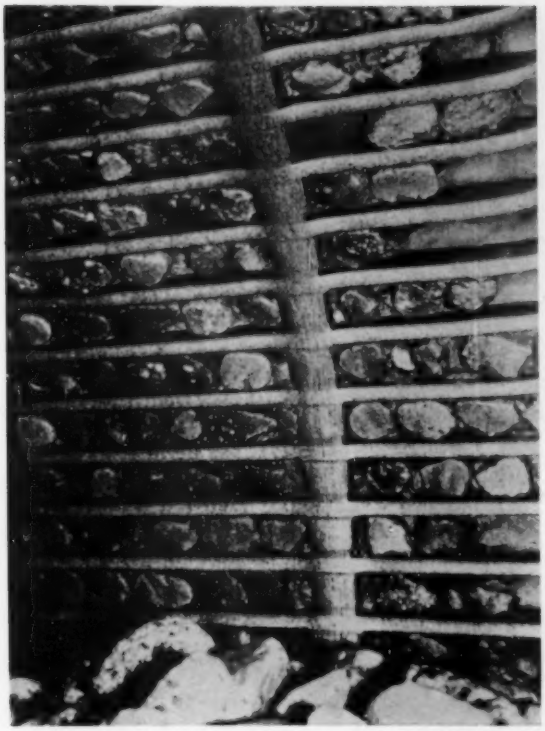
All the mills are of the low-discharge type, with internal screens and lifter scoops fitted against the discharge ends. Trunnion bearings are of grease-lubricated white metal and trunnion liners of manganese steel. For 8-ft diam mills the bore of the inlet trunnions increases from 15 in. to 18 in. over 42 in. The outlet trunnion liner has a parallel bore of 12 in. For 12-ft mills the bore of both inlet and outlet trunnion liners is parallel and is 24 in. in each case.

With two exceptions all the mills are equipped with feed hoppers, fitted with heavy molded rubber gaskets. The whole assembly is spring-loaded to press against the rotating mill trunnion. Life of these gaskets varies from a few months to about a year. Recently it has been found advisable to have them molded with a metal core or else backed by a metal plate to which they adhere.

The mills of this group have been equipped during recent years with a wide variety of linings, and new types or modifications of older types have continually been designed and tested with a view to ultimate standardization. The liner situation is therefore in a state of flux. Data on typical linings

Table I. Union Corp. Ltd. Mills in Operation During 1957

Mine	Year Milling Commenced	Tons Milled per Month	Grade of Ore Dwt per Ton	Rod Mills, Primary		Ball Mills, Secondary		Pebble Mills						Total Mills
								Primary		Secondary		Tertiary		
				Dimensions, Ft	No.	Dimensions, Ft	No.	Dimensions, Ft	No.	Dimensions, Ft	No.	Dimensions, Ft	No.	
East Geduld Mines Ltd.	1931	135,000	6.37	—	—	—	—	8 x 16	5	6½ x 20	14	8 x 16	6	25
Geduld Propty. Mines Ltd.	1908	95,000	3.43	—	—	—	—	—	—	5½ x 22 6 x 20	9 9	—	—	18
Grootvlei Propty. Mines Ltd.	1938	196,000	4.43	—	—	—	—	8 x 16 12 x 16	6 1	8 x 16 12 x 16	14 1	8 x 16	6	28
Marievale Conc. Mines Ltd.	1939	71,000	5.45	6 x 12 8 x 12	1 1	8 x 8	2	—	—	8 x 16	4	—	—	8
St. Helena Gold Mines Ltd.	1951	116,000	6.02	8 x 12	3	—	—	12 x 16	1	8 x 16	3	8 x 16 12 x 16	6 1	14
Van Dyk Cons. Mines Ltd.	1938	77,000	3.66	—	—	—	—	8 x 16	4	8 x 16	8	—	—	12
Totals		667,000			5		2		17		62		19	105



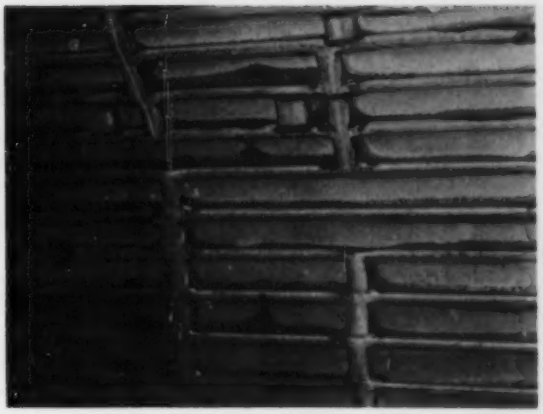


Fig. 1–(Above) Coarse pebbles packed between the Osborn bars form a semi-autogenous lining, reducing operating cost. Fig. 2–(Above, right) As bars wear down, toward the end of liner life, they no longer hold packing, and wear becomes more rapid. Fig. 3–(Right) These manganese-steel bars in a 12x16-ft primary mill are about 3½ in. in cross section, spaced about 15 in. apart and bolted down on grids worn to ¾ in. deep. Spaces between bars pack with pebbles and partly ground feed, so that only the bars are worn.

are given in Tables II-IV, arranged according to milling stage and type of lining. Three metals, in general, are used in construction of these linings, namely: white (cast) iron, with a Brinell hardness averaging 227; manganese (cast) steel, with a Brinell hardness averaging 285; and rolled steel bars, with a Brinell hardness of 183, containing 0.72 pct C, 0.86 pct Mn, 0.26 pct Cr, 0.36 pct Si, and 0.02 pct Ni. These steel bars form the Osborn bar liner referred to later.

Table II lists data concerning inlet end liners, which are cast in sections of appropriate size and bolted to the ends of the mills. To compensate for uneven rate of radial wear, their cross-sectional profiles vary in thickness according to operating experience.

Solid white-iron liners 3 to 4 in. thick have proved very satisfactory in the past, but they are heavy to handle and occasionally fracture toward the end of their lives. The more recent manganese-steel grid and plate developed at Marievale Consolidated Mines for its ball milling stage is lighter and more economical. The grids are open-work castings designed to allow the grinding medium to pack solidly; they are backed by plates about ¾ in. thick, which protect the shell when the grids eventually wear too thin to maintain the packing. Data are given for average life of both the steel grid and the plate. It will be seen that the plate backing outlasts many grids.

Table III lists data for shell liners. The peripheral speed refers to the mill shell liners less the thickness of half-worn liners. With the exception of the manganese-steel grid type, which is relatively new, two kinds of liners have been in use for many years: 1) Osborn bars are generally used in the primary and secondary milling stages of a three-stage unit and 2) white-iron blocks in the final stage. Both are held in place by thin plates driven by sledge hammer between the pieces making up the liner.

These boltless types have been adopted because the large pebbles used in the coarser milling stage will pack between the Osborn bars, as shown in Fig. 1, forming a semi-autogenous lining that reduces cost. As the bars wear down they can no longer hold their packing, as shown in Fig. 2, and wear becomes more rapid. The spacer bars can be used again in several relinings. In both cases the liners were well washed down before being photographed.

The white-iron block liners, cast in wave or sawtooth form, are used in the final milling stages because the smaller pebbles do not pack satisfactorily within the standard spacing of the Osborn bars.

Osborn bar liners consist of flat medium-carbon

Table II. Typical Mill Inlet End Line Data

Milling Stage	Liner Type	Mine	Mill		Average Liner Life, Days	Liner Wear	
			Dimensions, Ft	Speed, Rpm		Net Pounds per Horsepower-Day	Gross Pence per Ton Milled
Primary	Manganese steel, solid	Van Dyk	8 x 16	24.4	99	0.074	0.306
Primary	Manganese steel, solid	Grootvlei	12 x 16	20.2	51	0.126	0.925
Primary	Manganese steel, pocketed	St. Helena	12 x 16	20.5	61	0.068	0.466
Primary	White iron, solid	Grootvlei	8 x 16	24.8	90	0.101	0.157
Secondary three-stage	Manganese steel, grid and plate	Marievale*	8 x 8	19.6	250 to 1500	0.031	0.077
Secondary three-stage	White iron, solid	St. Helena	8 x 16	25.0	110	0.079	0.121
Secondary three-stage	White iron, solid	Grootvlei	8 x 16	19.6	114	0.081	0.240
Secondary two-stage	Manganese steel, solid	Grootvlei	12 x 16	20.2	73	0.072	0.701
Secondary two-stage	White iron, solid	Van Dyk	8 x 16	19.6	196	0.059	0.238
Secondary two-stage	White iron, solid	Van Dyk	8 x 16	22.8	167	0.066	0.279
Tertiary	Manganese steel, grid and plate	Marievale**	8 x 16	19.6	206 to 2744	0.018	0.121
Tertiary	White iron, solid	St. Helena	12 x 16	20.5	126	0.052	0.246
Tertiary	White iron, solid	St. Helena	8 x 16	25.0	162	0.058	0.165
Tertiary	White iron, solid	Grootvlei	8 x 16	19.6	260	0.041	0.052

* Ball mill.
** Composite load.

Table III. Typical Mill Shell Data

Milling Stage	Liner Type	Mine	Mill		Average Liner Life, Days	Liner Wear	
			Dimensions, Ft	Peripheral Speed, Fpm		Net Pounds per Horsepower-Day	Gross Pence per Ton Milled
Primary	Osborn bar	Grootvlei	8 x 16	597	117	0.246	0.755
Primary	Osborn bar	Van Dyk	8 x 16	588	113	0.382	1.025
Primary	Osborn bar	Grootvlei	12 x 16	740	58	0.423	1.326
Secondary three-stage	Manganese steel grids	Marievale*	8 x 8	472	334	0.062	0.177
Secondary three-stage	Osborn bar	Grootvlei	8 x 16	597	242	0.246	0.783
Secondary three-stage	White iron blocks	St. Helena	8 x 16	602	180	0.511	0.605
Secondary two-stage	White iron blocks	Van Dyk	8 x 16	472	460	0.196	0.598
Secondary two-stage	White iron blocks	Van Dyk	8 x 16	549	324	0.258	0.851
Tertiary	White iron blocks and manganese steel key bars	St. Helena	12 x 16	751	178	0.151	1.171
Tertiary	White iron blocks	Grootveli	8 x 16	472	575	0.185	0.341
Tertiary	White iron blocks	Marievale**	8 x 16	472	538	0.137	0.339
Tertiary	White iron blocks	Marievale**	8 x 16	590	314	0.240	0.604

* Ball mill.
** Composite load.

Table IV. Typical Mill Screen Data

Milling Stage	Liner Type	Mine	Mill		Average Screen Life, Days	Liner Wear	
			Dimensions, Ft	Speed, Rpm		Net Lb per Horsepower-Day	Gross Pence per Ton Milled
Primary	Manganese steel, solid	Grootvlei	12 x 16	20.2	90	0.083	0.537
Primary	Manganese steel grid and plate	Van Dyk	8 x 16	24.4	160 to 710	0.025	0.139
Primary	White iron, solid	Grootvlei	8 x 16	24.8	168	0.047	0.099
Primary	White iron, solid	St. Helena	12 x 16	20.5	78	0.050	0.508
Secondary three-stage	Manganese steel grid and plate	Marievale*	8 x 8	19.6	185 to 334	0.026	0.083
Secondary three-stage	White iron, solid	St. Helena	8 x 16	25.0	139	0.046	0.107
Secondary two-stage	Manganese steel grid and plate	Van Dyk	8 x 16	22.8	268 to 451	0.022	0.193
Secondary two-stage	Manganese steel, solid	Grootvlei	12 x 16	20.2	83	0.074	0.631
Secondary two-stage	White iron, pocketed	Van Dyk	8 x 16	19.6	262	0.023	0.201
Tertiary	Manganese steel grid and plate	Marievale**	8 x 16	24.5	354 to 1025	0.011	0.088
Tertiary	White iron, solid	St. Helena	8 x 16	25.0	180	0.041	0.179
Tertiary	White iron, solid	St. Helena	12 x 16	20.5	108	0.054	0.366

* Ball mill.
** Composite load.

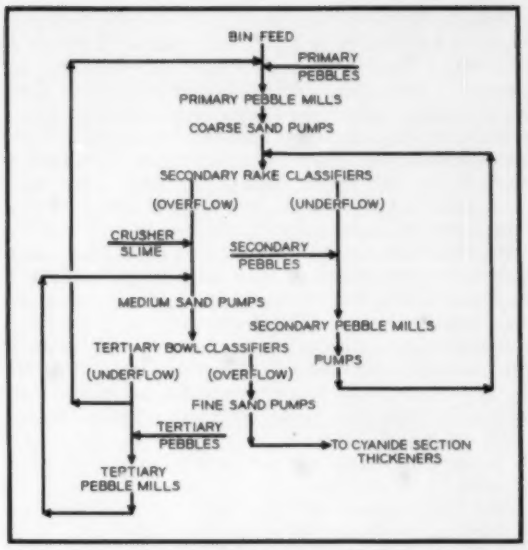


Fig. 4—In the East Geduld Mines plant the primary and tertiary mills alternate in one row. This accounts for division of sand flow from the tertiary bowl classifiers.

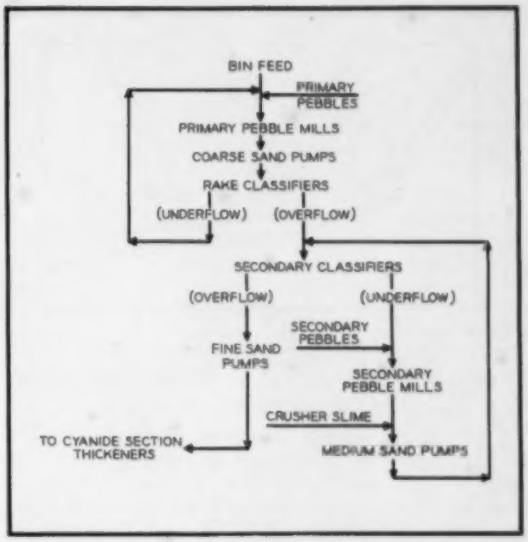


Fig. 5—Flowsheet of Van Dyk Consolidated Mines Ltd.

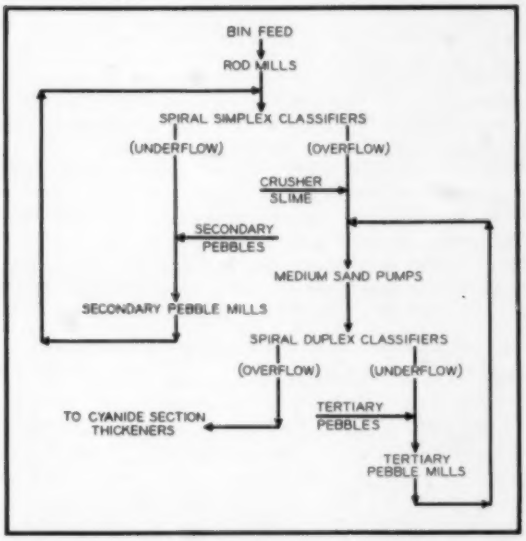


Fig. 6—Original flowsheet at St. Helena Gold Mines Ltd.

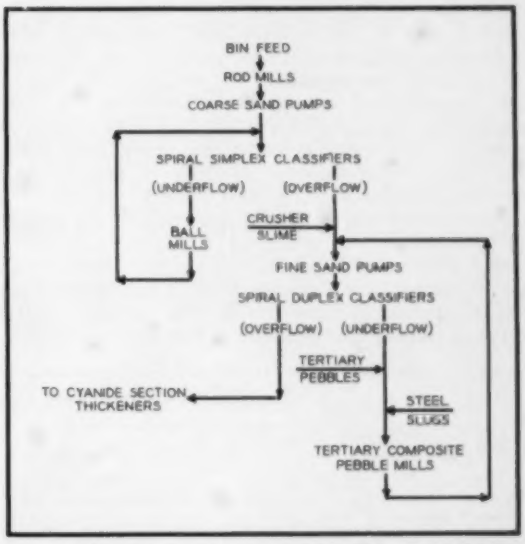


Fig. 7—Three-stage circuit of Marievale Consolidated Mines Ltd. incorporates rod, ball, and composite-load.

steel bars, 4½ in. deep by 1¼ in., tapering to ¾ in. These bars are placed on edge and separated at their 1¼-in. bases by flat steel spacers 3 in. wide and ¾ in. thick. They are further separated by cast-iron chocks, 3 x 2¼ x 2⅞ in., spaced about 2 ft apart, so that in a lined mill these appear as rings. An anti-creep bar is bolted to the shell along the full length of the mill to key the first and subsequent bars up against it and also to prevent any movement of the installed liners.

In the mills 16 ft long, Osborn bar liners are installed in two sectional rings. Steel jacks are set tightly against wooden blocks across the mill's diameter. The blocks press the liners hard against the shell, holding the bottom semi-circular lined section in place so that the mill can safely be turned through 180° while the assembly is completed. When properly installed these boltless liners are rarely displaced.

Because they are larger in diameter, liners in the 12x16-ft mills are of the bolted type. When Osborn bar liners are used they are installed in groups of 12 bars keyed up against wedge-shaped manganese-steel bars bolted to the shell. In the final-stage mills manganese-steel wedge bars, bolted to the shell, hold white cast-iron blocks in place.

The manganese-steel grid and plate-type liner, developed at Marievale for ball mills, bids fair to replace other shell liners used in this group of mines because it is relatively inexpensive per ton milled and is light and easy to install. The grids are cast in sections 45x15 in. and are 4 in. deep, forming openings 10 in. long by 3½ in. wide. They are backed by ½-in. thick sections of mild steel plate, and the whole is bolted to the shell. The grinding media pack within the openings, forming a partial autogenous liner as in the case of the Osborn liners, but the main advantage over the Osborn bar is the

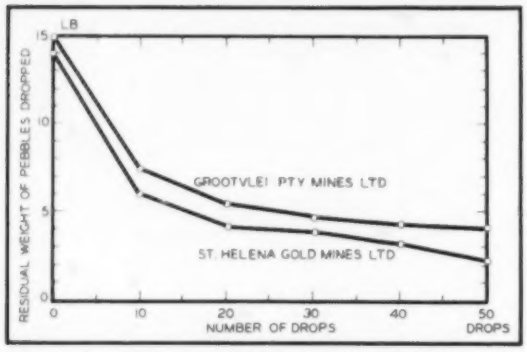


Fig. 8—Comparative results of pebble dropping test.

labor-saving installation.

A recent interesting development of this liner is the surprising fact that when manganese-steel bars, about 3½ in. square in cross section, are bolted down in a 12x16-ft primary mill parallel to the mill axis and spaced about 15 in. apart on grids worn down to only ¾ in. deep, the space between these bars packs solid with pebbles and partly ground feed, so that only the bars are worn. This system is illustrated in Fig. 3, where the packing can be clearly seen in the experimental end section next to the discharge screen. The packing was so dense that a chisel was required to dislodge it. The mill in this instance had not been washed down, so that most of the screen holes are full of fine sand but not blocked. Under work currently being conducted, this type of liner shows a good deal of promise, but like the Osborn bars, it does collect and retain a considerable amount of free gold within the pebble packing.

Mill doors are lined with one-piece blocks with a 1-in. center hole through which a graduated steel rod is inserted at least once a shift to measure the depth of pebble load relative to the axis of the mill. A wooden or rubber plug inserted into the hole prevents leakage of pulp. In this connection it might be mentioned that for optimum milling conditions the operators maintain the pebble loads in primary mills at about 5 in. below their axes, and in the final milling stages at approximately axis level. The 8x16-ft mills have one door each, but the 12x16-ft mills have two doors, placed at 180° from each other and staggered along the length of the mill to avoid undue weakening of the shell.

Table IV lists data for mill screens. White cast-iron solid screens were used almost exclusively in the past and are still used in great numbers, but new types made of manganese steel will probably replace white cast-iron in due course. All types of screens, however, are bolted in sections to the discharge end of their respective mills and are pierced with a multiplicity of circular holes varying from ½ to ⅞-in. diam on the new wearing face and tapering to larger diameters in the direction of pulp flow, at a conical angle of about 5°. All types of screens are bolted hard up against cast-steel lifter scoops cast in sections, varying in depth but averaging 4 in. These scoops discharge pulp from the mill through the outlet trunnions so that the fluid pulp within the mill can be maintained at a low level. This in turn allows greater horsepower to be absorbed by the mill load. Milling capacity is greater, therefore, than in mills of the overflow pulp type.

As in the case of the inlet-end liners, the cross-sectional profiles of screens vary in thickness to compensate for uneven radial wear, but white-iron screens have a tendency to fracture if worn too thin. For this reason, solid manganese screens were introduced in the primary milling stages, where there is greater impact from the larger pebbles.

Recent designs for manganese-steel grid and plate-type screens are similar to those developed for the inlet-end liners, but in this case the dimensions of the apertures of the grids are made larger so that they will not pack with grinding media. The

Table VI. Average Annual Classification Data for Milling Circuits

	East Geduld, 1957 (See Fig. 4)	Marievale, 1955 (See Fig. 7)	St. Helena, 1954 (See Fig. 6)	Van Dyk, 1957 (See Fig. 5)
Primary Classifiers				
Type	—	—	—	Duplex rake
Dimensions	—	—	—	8x18 ft
Number	—	—	—	4
Feed, tons per classifier-day	—	—	—	1551
Underflow, tons per classifier-day	—	—	—	805
Overflow, tons per classifier-day	—	—	—	746
Overflow, moisture, pct	—	—	—	42.7
Overflow, +200 mesh, pct	—	—	—	68.2
Classifier, 200-mesh efficiency, pct	—	—	—	37.6
Secondary Classifiers				
Type	Duplex rake	Simplex spiral High-weir	Simplex spiral High-weir	*
Dimensions	8x18 ft	72 in.	72 in.	
Number	14	3	3	—
Feed, tons per classifier-day	1173	5915	2523	2777
Underflow, tons per classifier-day	760	4676	1182	1966**
Overflow, tons per classifier-day	413	1239	1341	811
Overflow, moisture, pct	82.6	73.5	52.6	87.8
Overflow, +200 mesh, pct	38.7	56.2	65.9	15.3
Classifier, 200-mesh efficiency, pct	64.1	61.4	38.0	66.4
Tertiary Classifiers				
Type	Duplex rake Bowl	Duplex spiral Submerged	Duplex spiral Submerged	—
Dimensions	8x18 ft bowl	54 in.	54 in.	—
Number	6	4	6	—
Feed, tons per classifier-day	1390	1586	2258	—
Underflow, tons per classifier-day	472	915	1625	—
Overflow, tons per classifier-day	918	671	633	—
Overflow, moisture, pct	86.2	88.0	86.2	—
Overflow, +200 mesh, pct	17.0	15.0	28.0	—
Classifier, 200-mesh efficiency, pct	64.8	74.7	63.2	—

* 3 @ 16-ft quadruplex rakes with 18-ft bowl and 1 @ 54-in. duplex spiral.
** Each classifier feeds two secondary mills.

¾-in. plate behind the grid is of manganese steel and is pierced by a great number of tapered holes. As in the case of the inlet-end liners, the plate outlasts several protective grids.

Despite the higher cost of manganese steel, this type of screen can compete economically with white-iron screens. The sections are relatively light and are easier to install, they do not fracture towards the end of their life, and because the screen proper is thinner, there can be more holes per unit area. Because the holes are shallower, they are less likely to become choked with the smaller sizes of grinding media. Where high-circulating load milling is practiced, however, plain cast screens are more suitable, as the grids reduce the scouring action of the pulp across the holes that tend to become choked.

All sections of all mills are lined in place by a European tube mill reliner, an assistant, and a gang of about eight natives.

Constant vigilance is necessary to guard against theft of concentrate, which is readily disposable through illicit channels. A regulation of the Gold Law requires the presence of at least two Europeans when high-grade material is handled. In this respect it should be pointed out that fine metallic gold, usually not visible, lodges in the joints and also works its way behind tube mill liners as a very high-grade concentrate. The total quantity of gold a lined mill can adsorb varies with the type of liner. A 12x16-ft primary mill with a solid block liner does not absorb much gold, but when fitted with an Osborn bar liner it can absorb a considerable amount within and behind the metal, and a substantial quantity within the packed pebbles. Milling in cyanide solution is not practiced.

To reline the shell of an 8x16-ft mill, the whole load is emptied onto the concrete floor and shoveled back when the job is completed. The load averages 20 tons. In the case of the 12-ft mills, however, the load is not emptied, as there is enough head room for the mills to be relined by workers standing on the load. During relining, the mills are very slowly rotated by a motorized barring gear. Depending on rate of wear along the length of the mill, it is customary to reline only part of the shell liner at one time. An 8x16-ft mill is lined with Osborn bars in two sections, and one section can be relined and the mill reloaded within an 8-hr shift. Since the law prohibits milling operations on Sundays in any reduction works erected since 1911, it is common practice, under special permit, to reline mills on that day in order to minimize loss of running time.

Operational Data: Flowsheets of four milling plants are given to illustrate different types of Group

Table V. Average Annual Data for Four Milling Circuits

	East Geduld, 1957 (See Fig. 4)	Marievale, 1955 (See Fig. 7)	St. Helena, 1954 (See Fig. 6)	Van Dyk, 1957 (See Fig. 5)
Primary Mills				
Type	Pebble	Rod	Rod	Pebble
Number and dimensions	5 @ 8x16 ft	1 @ 6x12 ft 1 @ 8x12 ft	3 @ 8x12 ft	4 @ 8x16 ft
Average mill speed, rpm	24.0	20.8 to 19.4	18.6	24.4
Power consumed per mill, hp	289	187 to 366	293	299
Bin feed, + ⅜ in., pct	38	3	63	16
Bin feed, tons per mill-day	978	839 to 1773	1356	700
Sand, tons per mill-day	139	—	—	805
Pebbles, tons per mill-day	37	—	—	46
Pebbles, average weight, lb	11.1	—	—	14.9
3½-in. rods, lb per horsepower-day	—	4.80 to 5.60	7.45	—
Total feed per mill-day, tons	1154	839 to 1773	1356	1551
Discharge moisture, pct	18.1	19.7	—	21.6
Power per ton −200 mesh produced, kw-hr	30.4	25.7 to 24.1	24.2	27.0
Secondary Mills				
Type	Pebble	Ball	Pebble	Pebble
Number and dimensions	14 @ 6½x20 ft	2 @ 8x8 ft	3 @ 8x16 ft	8 @ 8x16 ft
Average mill speed, rpm	26.0	19.6	25.0	20.0
Power consumed per mill, hp	217	256	292	248
Sand feed per mill-day, tons	760	4676	1182	983
Pebbles per mill-day, tons	13	0	25	19
Pebbles, average weight, lb	3.3	—	0.9	—
Pebbles, screen analysis, pct:				
+2 in.	—	—	—	78.3
−2 in. +1½ in.	—	—	—	17.9
−1½ in. +1 in.	—	—	—	2.3
−1 in.	—	—	—	1.5
Steel per horsepower-day, lb	—	7.81	—	—
Total feed per mill-day, tons	773	4676	1207	1002
Discharge moisture, pct	21.8	26.1	—	31.3
Power per ton −200 mesh produced, kw-hr	24.2	15.6	23.5	20.9
Tertiary Mills				
Type	Pebble	Composite Load	Pebble	—
Number and dimensions	6 @ 8x16 ft	4 @ 8x16 ft	6 @ 8x16 ft	—
Average mill speed, rpm	19.5	23.3	25.0	—
Power consumed per mill, hp	233	367	274	—
Sand feed per mill-day, tons	360	915	1625	—
Pebbles per mill-day, tons	19	15	19	—
Pebbles, screen analysis, pct:				
+2 in.	11.3	45.1	50.5	—
−2 in. +1½ in.	18.9	38.5	39.4	—
−1½ in. +1 in.	36.6	15.1	8.9	—
−1 in.	33.2	1.3	1.2	—
Slugs per horsepower-day, lb	—	3.65	—	—
Total feed per mill-day, tons	379	930	1644	—
Discharge moisture, pct	32.3	28.8	—	—
Power per ton −200 mesh produced, kw-hr	26.6	23.8	21.0	—
Complete Milling Plant				
Total tons per plant-day	5530	2728	4119	3265
Overall circulating load ratio	2.4 to 1	4.8 to 1	3.4 to 1	2.4 to 1
Screen analysis of final pulp (+200 mesh), pct	17.0	15.0	28.0	15.3
Addition of steel per ton milled, lb	—	4.53	0.74	—
Cost per ton milled, pence	21.1	28.6	24.3	20.8
Power per ton milled (mills only), kw-hr	19.1	16.7	14.7	17.4
Power per ton −200 mesh produced (mills only), kw-hr	26.0	21.6	22.3	22.8
Total cost per ton −200 mesh produced (mills only), pence	28.7	37.0	36.7	27.3

Table VII. Primary Pebble Self-Comminution Tests

	Development Pebbles	
	Grootvlei	St. Helena
Initial pebble load, lb	20,000	20,000
Number of pebbles	1,412	1,502
Average weight of pebbles, lb	14.2	13.3
Duration of grind, min	15	15
Final load, lb	14,497	15,878
Final load, + 1½ in., lb	13,252	11,378
Number of pebbles, + 1½ in.	5,325	6,344
Average weight of pebbles + 1½ in., lb	2.49	1.79
Final load of original, pct	72	79
Final load, + 1½ in. of original, pct	66	87

Screen Mesh Sizes, In.	Percentage by Weight				Average Weight of Screened Fractions after Grind, Lb	
	After Grind		Of Original Charge			
	Grootvlei	St. Helena	Grootvlei	St. Helena	Grootvlei	St. Helena
+ 5	24.3	17.6	17.6	14.0	10.2	14.1
+ 4	63.6	31.8	46.1	25.3	6.7	6.1
+ 3	77.4	50.6	56.1	40.2	2.9	2.9
+ 2	87.9	65.5	63.7	52.0	0.9	1.1
+ 1½	91.5	71.8	66.3	56.9	0.3	0.4
− 1½	8.5	28.2	33.7	43.1	—	—
	100.0	100.0	100.0	100.0	—	—

milling circuits. Details of their equipment and representative milling data for each of these circuits are given in Table V. Classification data are presented in Table VI.

It will be appreciated that direct comparisons between these four milling plants cannot easily be made, since operating conditions differ considerably as to addition of steel, number of milling stages, kilowatt-hours per ton milled, screen analyses of bin feed and final pulp, magnitude of circulating load and, to a lesser degree, relative hardness of ore.

Fig. 4 is the flowsheet of the East Geduld Mines mill, which is the oldest all-sliming plant of the Group and embodies a three-stage all-pebble-milling circuit. It will be noted that the circuit is rather unusual in that the sand from the tertiary bowl classifiers is split between the tertiary and primary pebble mills. This is done because the primary mills alternate with tertiary mills in one row.

Table V shows that overall power consumption per ton of −200 mesh produced is somewhat higher than that of the other plants given, owing to the small load in the primary and tertiary milling circuits. In the tertiary circuit, particularly in cold weather, this load has been found necessary to avoid or reduce sliming in the thickening plant, which consists mainly of two-deck thickeners. Milling costs are rather higher than for the Van Dyk two-stage pebble plant.

The flowsheet of this Van Dyk Consolidated Mines plant is presented in Fig. 5. Relevant operational data are given in Table V. This plant has the lowest costs of the four mills tabulated. It will be noted also that power consumption per ton of −200 mesh produced is less than for the East Geduld all-pebble milling plant and is comparable with power consumption in the other two mills, where steel grinding media are employed in certain stages.

Fig. 6 is the original flowsheet for the three-stage plant of St. Helena Gold Mines Ltd., where rod mills are used in the primary stage. St. Helena's reduction works were the first to be brought into operation in the Orange Free State's new gold field. To advance the date of production it was necessary to design the mill before enough mine development work had been carried out to reveal the milling properties of the ore, which was reported to be more brittle than the Transvaal Witwatersrand ore. This was disturbing information, since there would be a risk in incorporating a primary pebble milling stage if the primary pebbles broke up. A test was therefore devised to obtain a rough quantitative comparison between the St. Helena ore and ore from the Grootvlei Propty. Mines Ltd., a typical East Rand Group mine. Selected pieces of ore were dropped 50 times from a height of 9 ft onto a large solid manganese casting, chipping off part of the ore. Each residual piece was weighed after every ten drops. Comparative results of these tests are shown in Fig. 8.

Final residual weight of the Grootvlei pebbles was almost double that of the St. Helena pebbles. Owing to incipient planes of weakness, moreover, a greater number of St. Helena pebbles broke up during the first few drops. These were excluded from the test data.

Table VIII. Metallurgical Data per Pebble Milling Unit

	Van Dyk Cons. Mines Ltd. 1957				Grootvlei Propty. Mines Ltd. January-April 1958			
	Tons Per Calendar-Day		Moisture, Pct	+200 Mesh, Pct	Tons Per Calendar-Day		Moisture, Pct	+200 Mesh, Pct
	Dry Solids	Water			Dry Solids	Water		
Primary Pebble Mills								
Bin feed	629	19	3.0	94.2	1381	43	3.0	96.9
Primary classifier underflow	723	239	24.8	91.9	2958	1097	27.1	88.4
Primary pebbles	41	—	—	—	150	—	—	—
Added water	—	125	—	—	—	395	—	—
Discharge	1393	383	21.6	80.5	4489	1535	25.5	76.0
Primary Classifiers								
Primary mill discharge	1393	383	21.6	80.5	4489	1535	25.5	76.0
Added water	—	356	—	—	—	1783	—	—
Total feed:	1393	739	34.7	80.5	4489	3318	42.5	76.0
Underflow	723	239	24.8	91.9	2958	1097	27.1	88.4
Overflow	670	500	42.7	68.2	1531	2221	59.1	52.1
Secondary Pebble Mills								
Secondary classifier underflow	1799	752	29.5	86.8	3678	1629	30.7	80.5
Secondary pebbles	35	—	—	—	114	—	—	—
Added water	—	82	—	—	—	586	—	—
Discharge	1834	834	31.3	65.8	3792	2215	36.9	62.6
Secondary Classifiers								
Primary classifier overflow	670	500	42.7	68.2	1531	2221	59.1	52.1
Secondary mill discharge	1834	834	31.3	65.8	3792	2215	36.9	62.6
Crusher slime	34	63	65.0	29.3	—	—	—	—
Added water	—	4691	—	—	—	9871	—	—
Total feed:	2538	6088	70.5	65.6	5323	14307	72.9	59.6
Underflow	1799	752	29.5	86.8	3678	1629	30.7	80.5
Overflow	739	5336	87.8	15.3	1645	12678	88.5	12.9

Table IX. Supplementary to Table VIII

	Van Dyk 1957	Grootvlei January-April 1958
Number of primary mills per unit	1	1
Number of secondary mills per unit	2	1
Size of pebble mills, unlined shell	8x16 ft	12x16 ft
Speed of primary pebble mills	24.4 rpm	20.2 rpm
Speed of secondary pebble mills	19.6 rpm	20.2 rpm
Critical speed of primary mills with half-worn liners	88.3 pct	90.2 pct
Critical speed of secondary mills with half-worn liners	71.0 pct	90.2 rpm
Average power of primary mills per unit	299 hp	868 hp
Average power of secondary mills per unit	496 hp	828 hp
Average weight of pebbles, primary mills	14.9 lb	10.4 lb
Screen analysis of pebbles, secondary mills:		
+2 in.	78.3 pct	36.3 pct
−2 in. +1½ in.	17.9 pct	36.5 pct
−1½ in. +1 in.	2.3 pct	24.6 pct
−1 in.	1.5 pct	2.6 pct
Primary classifiers	1 @ 8 ft wide duplex rake	1 @ 36 in. x 15° cone cyclone
Secondary classifiers	1 @ 16 ft wide quadrupiex rake with 18 ft bowl	4 @ 27 in. x 15° cone cyclones
Tons milled per housepower-day	1.026	0.959
Tons −200 mesh produced per ton milled	0.765	0.845
Kilowatt-hours per ton −200 mesh produced, primary	27.0	23.0
Kilowatt-hours per ton −200 mesh produced, secondary	20.9	21.1
Kilowatt-hours per ton −200 mesh produced, overall unit	22.8	22.1

To substantiate the test results, a shipment of primary-sized pebbles from the development ore dump at St. Helena was railed to Grootvlei for grinding tests against similar-sized pebbles from development ore from that mine. In each instance 10 tons were loaded into an empty selected mill (about half a normal mill load) and ground for 15 min at 24.5 rpm. Water was allowed to flow through the mill to wash out grit and slime through the ¾-in. holes in the mill screen. At the end of the tests the loads were dumped. The partly worn pebbles were screened through square mesh and each fraction was weighed and the number of pebbles counted, down to the +1½-in. size.

The results, given in Table VII, showed that the St. Helena pebbles wore away more quickly, for the +1½-in. pebbles in the original load, 57 pct remained, compared with 66 pct in the case of the Grootvlei pebbles. On the basis of this data, 8x12-ft rod mills were installed for the primary stage, as the 6x12-ft test mill installed in the Marievale reduction works had proved satisfactory and more economical for primary-stage milling than the ball mills operating at the same mine. It has since been established that it would have been quite safe and more economical to install primary pebble mills. A 12x16-ft primary pebble mill later installed in a plant extension has operated successfully, and a secondary primary mill of the same size is being installed in a new plant extension now under construction. A study of the savings in rod mill costs indicates that it should be profitable to convert the original rod mills to pebble mills.

Average milling data for 1954, presented in Table V, have been selected as representative of results from the original flowsheet before the first extension incorporating primary pebble milling came into operation. Screen analysis of the bin feed has since been reduced to 7 pct +⅜ in. The cost per ton milled given would be higher under 1957 prices.

Table V reveals that although the overall power consumption per ton of −200 mesh produced is 0.6 kw-hr lower than that of Van Dyk, the cost per ton of −200 mesh produced is 9.5 pence higher for a considerably coarser final pulp. This is due in part to the additional cost of rods. In 1957, however, with improved metallurgical practice, together with the benefit from the additional primary pebble milling unit and larger throughput, this cost differential has been reduced to 5.6 pence per ton of −200 mesh produced.

Fig. 7 is a flowsheet of the Marievale milling plant and Table V presents relevant operational data for 1955. Data from this mine are included here because steel is added to each of the three-stage milling circuits in the plant, which incorporates rod milling, ball milling, and composite-load pebble milling.

Because the width of the reef on this mine is narrow, it was believed that there would not be enough large pebbles for primary pebble milling, and the plant was designed to accommodate ball mills. In 1948 the writer paid a visit to the London milling plant of Tennessee Copper Co., where he was able to inspect and discuss operation of a 6x12-ft rod mill. Following this consultation, an experimental rod mill of the same size was installed at Marievale to test its economy as compared with that of ball mills in operation at that same plant. This was the first rod mill installed in a South African gold milling operation.

The installation was followed by several larger rod mills in this and other mining groups, since it was proved that in primary stages rod mills are more economical for South African gold ore than ball mills. Following the success of the prototype, an 8x12-ft rod mill was installed in parallel in 1953. The 3½-in. rods added cost 4.3 pence per lb; 3-in. cast steel balls cost 3.1 pence per lb.

The practice of milling with composite loads is not uncommon in South African gold ore reduction works. It was originally introduced to overcome a

Table X. Economics of 12x16-ft Mills Vs 8x16-ft Mills

	8x16-Ft Mills Van Dyk 1957		8x16-Ft Mills Grootvlei January-April 1958	
Power Costs				
Kilowatt-hours per ton −200 mesh produced	22.8		22.1	
Cost per kilowatt-hour (assumed average), pence	0.4		0.4	
Cost per ton −200 mesh produced, pence		9.12		8.84
Liner Costs				
Net wear per horse-power-day, lb	0.352		0.489	
Net wear per ton milled, lb	0.343		0.510	
Averaging cost per pound worn, pence	7.41		9.37	
Cost per ton milled, pence	2.54		4.78	
Cost per ton −200 mesh produced, pence		3.32		5.66
Total cost (power plus liners), pence		12.44		14.50
Capital Cost				
Number of mills per unit	3		2	
Mills, driving equipment and electrical controls (not erected)	£42,000		£53,000	
Amortization: Cost per ton −200 mesh produced, pence		4.28		2.43
Total cost per ton −200 mesh produced, pence		16.72		16.93

Table XI. Data on Pebble Consumption, 1947

Primary Pebbles:

Mine	Mill Dimensions, Ft	Mill Peripheral Speed, Fpm	Pebble Average Weight Per Pebble, Lb	Pebble Consumption Tons Per Day	Pebble Consumption Tons Per Horsepower-Day
East Geduld	8x16	578	11.1	37	0.129
Grootvlei	8x16	597	12.3	41	0.138
Grootvlei	12x16	740	12.3	162	0.192
St. Helena	12x16	751	3.9	129	0.145
Van Dyk	8x16	588	14.9	46	0.154

Secondary Pebbles:

Mine	Mill Dimensions, Ft	Mill Peripheral Speed, Fpm	Pebble Average Weight Per Pebble, Lb	Pebble Consumption Tons Per Day	Pebble Consumption Tons Per Horsepower-Day
East Geduld	6½x20	462	3.3	13	0.059
Grootvlei	8x16	597	2.3	43	0.141
St. Helena	8x16	602	1.1	40	0.136

Tertiary Pebbles:

Mine	Mill Dimensions, Ft	Mill Peripheral Speed, Fpm	Pebbles Screen Analysis, Pct +2 In.	−2 +1 In.	−1 In.	Pebbles Consumption Tons Per Day	Pebbles Consumption Tons Per Horsepower-Day
East Geduld	8x16	450	11.3	55.5	33.2	19	0.082
Grootvlei	8x16	472	33.7	60.9	5.4	23	0.092
Marievale	8x16*	472	45.4	54.5	0.1	15	0.041
St. Helena	8x16	602	50.5	48.3	1.2	20	0.072
St. Helena	12x16	751	50.5	48.3	1.2	118	0.138
Van Dyk	8x16**	549	78.3	20.2	1.5	19	0.077

* Composite load.
** Two-stage milling circuit.

shortage of suitably sized pebbles. In the case of Marievale, it was introduced to increase plant throughput, up to the ultimate safe working capacity of the motors and reduction gears driving the mills. The slugs used are about 1½ in. long and cost 1.1 pence per lb, being cut from discarded drill steel.

As to the economics of composite loading, a favorable case can be made for its increasing the tonnage output of a given plant, either as a temporary expedient or because expansion is not warranted by the expected life of the mine. But no economic case can be made for using steel balls to increase fineness of grind of Witwatersrand gold ores as a means of obtaining a higher gold recovery at the present price of gold.

The plant at Marievale is now being expanded to increase output and to eliminate composite-load milling.

It will be observed that the ball mills operate with a higher circulating load than the other group milling circuits. The net result of this appears to be chiefly a saving in liner wear and power, but the tons of −200 mesh produced per mill-day remain virtually constant, since the increased production per horsepower-day is offset by the horsepower drawn. This is the net effect of increasing the circulating load.

It will also be apparent from the data given in Table V that because of the use of 4.53 lb steel per ton milled, the power consumed per ton of −200 mesh produced is 1.2 kw-hr less than that of the Van Dyk all-pebble-milling two-stage circuit, but because of the addition of steel, the cost per ton of −200 mesh produced is 9.8 pence greater than that of Van Dyk. These data emphasize the economic advantage of the South African general practice of pebble milling over all-steel milling.

COMPARISON OF 12X16 AND 8X16 MILLS IN SIMILAR CIRCUITS

Average operational data in Tables VIII and IX allow comparison between two pebble milling units incorporated within the reduction works of the Van Dyk Consolidated Mines and the Grootvlei Propty. Mines Ltd. These have been selected as being of interest because, although both are two-stage units, each in closed circuit with its respective classification equipment, they differ in the size, speed, and number of mills per unit as well as in type of classification equipment, since the Van Dyk unit is a mechanical type and the Grootvlei a hydroclone unit. In this article, *calendar-days* include time lost through normal stoppages as opposed to *mill-days*, which represent 100 pct running time.

It will be noted that despite wide disparity of internal metallurgy, overall power consumption per ton of −200 mesh produced is of much the same order in each case, being 0.7 kw-hr per ton less for the Grootvlei unit despite a finer screen analysis of final pulp. The primary mill of this latter unit operated most of the time in conjunction with the Williamson pebble mill automatic controller, designed by the Group research metallurgist, J. E. Williamson.

The automatic controller senses the first differential of power consumed cyclically by a mill and controls the mean rate of pebble addition so that the power consumed by the mill is maintained very close to its maximum at all times. This maximum will vary with the quantity and quality of both the new feed and the circulating load, as well as with the moisture content of the mill. The device has been remarkably effective. Operational data have shown a mean increase of approximately 40 hp for a 12x16-ft pebble mill over that obtained by personal judgment of pebble addition.

It has already been mentioned that the trend of Group policy is to install large mills and to operate them at increased speeds. Table X compares the

Table XII. Screen Analysis of Composite Samples of one month's Operation, Van Dyk

	Mesh, Percentage Plus ¾ In.	4	8	14	28	48	100	200	Percent −200
Bin feed	11.4	52.2	68.2	73.5	80.8	86.6	90.3	93.1	6.9
Primary mill discharge	1.5	7.1	15.5	19.9	38.9	58.4	73.0	81.2	18.8
Secondary mill discharge	—	—	0.1	0.5	1.3	5.1	27.5	66.6	33.4
Primary classifier underflow	4.8	21.5	37.9	45.4	68.3	82.7	90.1	93.4	6.6
Secondary classifier underflow	—	4.1	6.1	8.4	13.2	24.4	54.4	91.9	8.1
Primary classifier overflow	—	—	—	2.8	16.9	41.3	61.8	73.6	26.4
Secondary classifier overflow	—	—	—	—	—	—	0.2	15.0	85.0

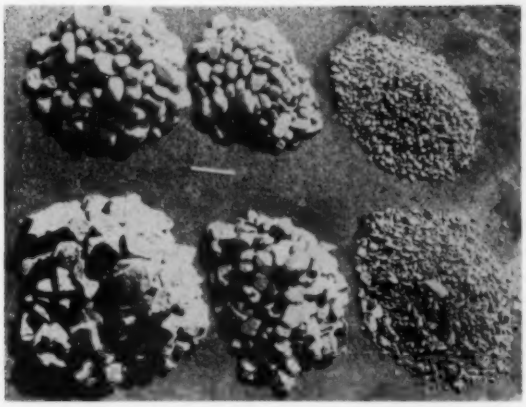


Fig. 9—Typical pebbles in East Geduld three-stage mill.

economics of 12x16-ft and 8x16-ft pebble mills per ton of — 200 mesh produced, based on data given in Tables VIII and IX and excluding all costs other than those of the mills. It will be noted that cost of power consumed under the given conditions is 0.28 pence per ton less in the case of the 12-ft mills, but this would be still less had the mill pulp screen analysis been equivalent to that of the 8-ft mills.

Liner replacement cost for the 12-ft mill is 2.34 pence per ton higher. This is chiefly due to the combination of larger-diameter mills and higher percentages of critical speed and partly to the higher cost of the manganese-steel liners used. It is probable that in due course this cost differential would be reduced by the use of less expensive metal. Amortization costs, calculated on the basis of 7.5 pct interest spread over 20 years, are 1.85 pence per ton less than for the 8-ft milling unit. The capital costs, quoted, include the mills with driving and control equipment only, exclusive of plant construction.

Total costs exceed those of the 8-ft unit by 0.21 pence per ton of — 200 mesh produced. This difference would be reversed by the additional amortization charges for a larger building necessitating an increased number of foundations; for equipment; and for more bins and also extra feed belts, particularly in view of the fact that the cost of the mills, *per se*, is only about one third of the complete milling plant. In addition, operational costs would be higher owing to a larger number of milling units to be controlled and maintained for an equivalent tonnage throughput. Finally, insofar as the milling of gold ore is concerned, there should be a net additional credit to the 12-ft unit of approximately 1.2 pence per ton for the extra gold that would be extracted from the finer pulp in the subsequent cyanide treatment process, since for the ores of this Group, within the normal range of screen analysis of mill pulp, the differential in extractable gold by cyanidation for every 1.0 pct of 200 mesh lies between 0.003 and 0.004 dwt gold per ton of ore milled.

With regard to increased speed alone, for mills of equivalent dimensions, a comparison showing the economic advantage has already been established.[3]

Pebble Consumption: Table XI lists average pebble consumption data for the Group mines for 1957. The peripheral speed refers to half-worn liners. Compared to steel ball consumption, pebble consumption is enormous, 200 to 300 lb per ton milled, depending on prevailing conditions. These data show that pebble consumption per horsepower-day progressively decreases from the primary to the tertiary milling stage, which also corresponds with a decrease in weight of pebble. In general, too, within milling stages, consumption per horsepower-day increases with both peripheral speed and diameter and appears to be more directly related to the latter. The large-diameter mills are thus heavy pebble consumers, but in view of the customary size distribution of run-of-mine ore this causes no embarrassment, particularly in the case of secondary and tertiary pebbles. In the case of primary pebble mills, it will be noted that for the St. Helena 12x16-ft mills an average pebble weight of 3.9 lb was fed, but in this case the bin feed was fine, being crushed to 6.9 pct + ⅜ in. Pebbles for any given milling stage should be as small as practicable, since this decreases both kilowatt-hours per ton of — 200 mesh produced and mill liner wear, but closely sized pebbles show no appreciable advantage in milling efficiency over those within a reasonable size range.

Fig. 9 shows typical pebbles used in the East Geduld three-stage milling plant. A 1-ft rule in the photograph gives a fair idea of their size.

RELATIONSHIP BETWEEN SCREEN ANALYSIS OF PULP, RATE OF MILLING, AND POWER TO PRODUCE —200 MESH MATERIAL

There is an empirical approximately linear relationship, shown in Fig. 10, between rate of milling and screen analysis of the final pulp. This relation-

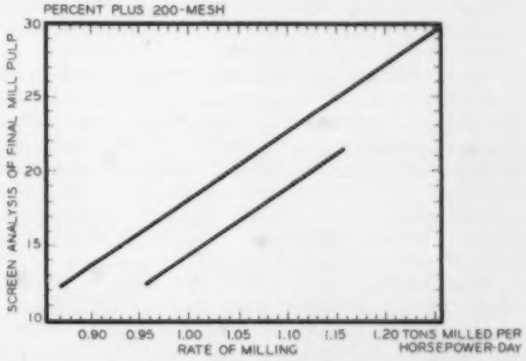


Fig. 10—Chart shows relationship between rate of milling per unit power and screen analysis of final pulp.

ship is useful in predicting performance of Group milling plants or in designing new plants and plant extensions. The slope of the curve appears to be nearly constant. For example, the equation of the upper curve in Fig. 10 is

$$y = 18 + 45\ (x\text{-}1) \qquad [1]$$

where x = the tons milled per horsepower-day and y = the percentge of + 200 mesh in the final mill pulp*

From such curves, interesting relationships can be deduced between the screen analyses of the final mill pulps and the power required per ton of material ground. An example of this is given in Fig. 11 for the Van Dyk milling circuit, milling at a rate of 1.0 tons per horsepower-day and producing a final

* In Group milling terminology it is customary to use either horsepower-days or kilowatt-hours, and also either percentage ±200-mesh, whichever is best to emphasize the point at issue.

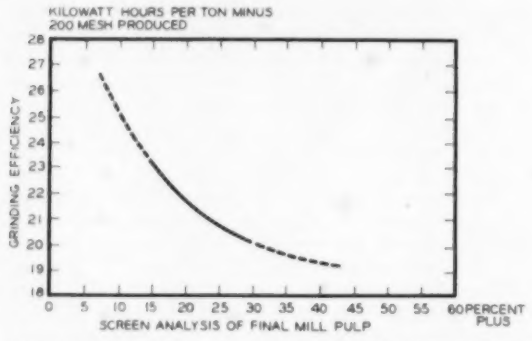


Fig. 11—Chart shows general theoretical shape of curve for relationship between screen analysis of final mill pulp and kilowatt-hours per ton of −200 mesh produced.

mill pulp at 15 pct + 200 mesh. It will be appreciated that a family of such curves must be constructed when, in practice, the screen analysis may vary according to the plant efficiency at a given milling rate. Monthly operating results for this mine over 18 consecutive months fitted these curves very closely. The writer is indebted to D. L. Carson, consulting metallurgist of the General Mining & Finance Corp., for developing an equation to fit this particular empirical curve:

$$y = (1.234 \times 10^{-18})\ x^7 + 18.9 \qquad [2]$$

where x = the percentage − 200 mesh and y = the kilowatt-hours per ton −200 mesh required to obtain such screen analysis. Using this equation, the curve has been extrapolated in broken lines in both directions to suggest a quantitative ratio for more extreme milling conditions.

Standardization of Screen Analysis Technique: In this group of mines, great care is taken to insure the highest practicable accuracy and concordance in screen analysis determinations, particularly for the 200 mesh determinations. Supervision of equipment and standardization of technique is the direct responsibility of the Group research metallurgist. Exhaustive tests were made of a large number of Tyled screens purchased about six years ago. Three of these which gave concordant results on a bulk sample of standard mill pulp from which the sulfides had been floated off were selected as master standards. One of the three screens was deposited in a safe as a final reference and has never been used since. The other two were used to standardize fresh bulk samples of sulfide-free mill pulps whenever these were required. The pulp samples are stored in air-tight containers, and the screens are renewed about every three years to be re-standardized against the standard bulk samples.

Upon request, the research laboratory supplies each mine of the Group with a numbered screen and a certificate giving its correction factor referred to the standard pulp sample. These screens are used by the mines for analyses of the monthly composite samples of cyanide residue pulp (considered to be the truest sample of the mill pulp) and also for their own standardization of all new 200-mesh screens, purchased on an average of one a month. Each mine submits a monthly composite of the cyanide residue to the Group research laboratory for check analysis. The screen analysis reported by the mine is required to agree within 0.5 pct.

All the Group mines retain, indefinitely, monthly composite samples of both original and cyanided mill pulp in air-tight glass preserving jars, in case any laboratory investigation is required into former milling or cyanidation practice.

Screen Analyses: Screen analyses of mill products through various mesh sizes are determined from time to time. Table XII shows analyses of composite samples of a typical month's operation at Van Dyk's two-stage pebble milling plant.

Infrasizer analyses of mill pulps are occasionally determined, as shown in Table XIII or a final mill pulp sample from the 12 x 16-ft two-stage milling unit of the Grootvlei Propty. Mines Ltd. Sulfur determinations of various fractions are included.

Table XIII. Typical Infrasizer Analysis of Final Pulp from the Grootvlei Two-Stage, 12-ft. X 16-ft. Milling Unit

Nominal Micron Size	Weight, Pct	Sulfur, Pct	
		Weight	Distribution
+56	14.4	1.0	14.4
−56 +40	17.1	1.2	20.5
−40 +28	12.9	1.2	15.4
−28 +20	9.8	1.2	11.8
−20 +14	8.1	1.1	8.9
−14 +10	4.2	1.3	5.5
−10	33.5	0.7	23.5

CONCLUSION

Steady progress in development of pebble milling in South Africa over half a century has brought the practice to its present state of efficiency. It has been established that for South African gold ores the use of pebbles as grinding media is considerably more economic than addition of steel balls or rods. Furthermore, the cost of producing suitable pebbles is unlikely to advance as fast as the price of steel grinding media. Although steel is sometimes employed in primary milling, recent experience has shown that, in nearly all cases, it could be eliminated by the preparation of finer mill feed.

The importance of accurate sampling and screen analysis cannot be too strongly stressed, and while pulp-density recording and controlling equipment is available, there is room for improvement. A further valuable development would be the continuous recording, coupled with automatic control, of equivalent screen analyses.

Owing to widespread staff shortages, progress since World War II has not been as rapid as could be wished and many details have not received the study they deserve. There is yet much to be learned about pebble milling. Reductions in both capital and operating costs are likely to be achieved principally by increased automatic control of large units and further simplification of the process.

The writer wishes to thank his colleagues, B. Fougner, assistant consulting metallurgist, and J. E. Williamson, research metallurgist, for assistance in preparing this article. He also extends thanks to technical staffs of the several Group reduction works whose operational data are partly recorded here, and to Union Corp. Ltd. for permission to publish this article.

Discussion of this article sent (2 copies) to AIME before Jan. 31, 1960, will be published in MINING ENGINEERING.

Reference

[1] O. A. E. Jackson: The Treatment of Ore from the Gold Mines of Union Corporation, Limited: a Summary of Metallurgical Practice. Accompanied by reply to discussion: Recent Development in Mineral Dressing. *The Institution of Mining and Metallurgy*, p. 623. London, 1953.

TIME ASPECTS OF GEOTHERMOMETRY

R. J. P. LYON

It is usually assumed[1, 2] that ore deposition is relatively slow, taking place over tens of thousands of years. Yet many syntheses and phase changes can be completed in the laboratory in a matter of hours, under essentially the same pressure and temperature conditions to be expected in nature.

Much has been written about geothermometry, and Ingerson's recent summary[3] can hardly be surpassed. Rather than review the whole field, this article will deal specifically with diffusion rates in solid solutions* of the sulfide minerals.

In the study and application of temperature-indicating phenomena to problems of ore genesis, the time factor has often been neglected. In the particular case of sulfide systems, the speed of unmixing and diffusion of the constituent phases in the solid solutions has seldom been considered when laboratory data are applied to the genesis of natural sulfide ores.

Chalcopyrite and Bornite Intergrowths: Chalcopyrite and bornite are copper iron sulfides often found in association. In many ores the individual grains appear to have mutual boundaries, but bladed intergrowths are quite common. Early workers in the field[4, 5] deduced that while these patterns could have been formed by replacement, they could be experimentally reproduced from the unmixing of solid solutions of the two previously homogenized at 475°C.

Much of the ore from Roan Antelope mine in the Rhodesian Copper Belt exhibits these bornite-chalcopyrite intergrowths, from which it has been deduced that the ores could have been subjected to a minimum temperature of 475°C. In several recent interpretations,[7] this temperature rise has been considered to result from a regional metamorphism of an original syngenetic copper-bearing sediment.

The same temperature rise to 475°C was suggested from similar intergrowths in the sulfide-bearing ore from the Happy Jack uranium mine[8] on the Colorado Plateau, although this temperature had a different origin.

In 1931 Schwartz[5] determined that 475°C represented the unmixing temperature of his bornite-chalcopyrite solid solutions but, more important, that the characteristic intergrowths of bornite and chalcopyrite could be preserved *only* if the solid solution were chilled quickly to room temperature. This significant corollary has been almost completely neglected by both Davis and Miller.[7, 8]

By suitably decreasing the cooling rate, Schwartz found that the original pattern of the intergrowth was reformed (Fig. 1). The cooling rate was critical. In cooling from 475°C to room temperature in

Fig. 1—Typical exsolution intergrowths of chalcopyrite in bornite. Micrographs reduced about one third. **a** *and* **b**: *Natural oriented intergrowths of chalcopyrite (black) in bornite (white) and segregation textures. Pine Vale ore. X90 (after Edwards, 1954).* **c**: *Natural intergrowth of tetrahedrite (black) in bornite (white). Pine Vale ore. X325 (after Edwards, 1954).* **d, e, f**: *Stages in unmixing of chalcopyrite (black) from same bornite solid solution (white). (After Schwartz, 1931.)* **d**: *Cooling from 475°C to room temperature in 5 min. X200.* **e**: *same solid solution, cooling time 1 hr. X100.* **f**: *same solid solution, cooling time 24 hr. X50.*

* The general subject of solid solution in structurally similar minerals is treated in many texts[1, 2, 4] and will not be further elucidated.

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5 min, thin blades of chalcopyrite showed in the bornite-rich matrix (Fig. 1d). With 60 min cooling from 475°C to room conditions, the blades were broader and fewer in number and had some enlarged areas from the coalescing of the chalcopyrite blebs (Fig. 1e). In 24 hr cooling time an equigranular mass of bornite and chalcopyrite resulted (Fig. 1f).

Two things should be learned from these simple experiments: 1) diffusion rates in many sulfides are rapid and 2) equigranular mineral associations can be the end products of complete unmixing of a solid solution. The obvious corollary here is that intergrowths represent arrested diffusion, and it is difficult to see how this could come about under P-T conditions of regional metamorphism. In this most suitable environment for diffusion, what caused these processes to cease?

Chalcocite and Bornite Intergrowths: Frueh[9] has shown that there is a high degree of disorder in the bornite lattice above 175°C, and Latsky[10] described appreciable diffusion rates of chalcopyrite in bornite occurring even at 220°C. Bornite-chalcocite intergrowths are also well known in ore from the deep levels at Butte,[11] and the characteristic grating texture of chalcocite blades in bornite matrix appears in ore from the bornite-rich central pipe at Bingham, Utah. There are many other examples of bornite-chalcocite intergrowths[11] whose origin may be due to rapid diffusion rates during unmixing of the solid solutions, but this geometrical association is often complicated by replacement textures. For sulfide assemblages, however, evidence for exsolution is more positive, and rapid diffusion rates have been recorded in experimental work.

Diffusion of $Fe_{1-x}S$ in $CuFeS_2$: Borchert[12] has graphed the rate of solid state diffusion of $Fe_{1-x}S$ (from dissociating pyrite) through a chalcopyrite matrix as a function of temperature. The graph, reproduced as Fig. 2, gives a good idea of the rapid movement of the $Fe_{1-x}S$, increasing ten thousand fold from 1 μ per hr at 375°C to 1 cm per hour at 600°C.

Diffusion of $Fe_{1-x}S$ in ZnS: The most complete study of solution, diffusion, and unmixing in a synthetic sulfide system is that of the $Fe_{1-x}S$-ZnS system as studied by Kullerud.[13] This is a concise, detailed discussion of the behavior of synthetic (Fe, Zn)S mixed crystals and contains a graph of the time required for exsolution of $Fe_{1-x}S$ (as pyrrhotite) from the mixed crystals plotted as a function of temperature. This curve, as seen in Fig. 3, shows exsolution of the $Fe_{1-x}S$ to have been completed in laboratory tests in four days at about 875°C, or in two years at 500°C. Extrapolation down to 400°, 300°, and 200°C yields the corresponding unmixing times to be 5, 17 and 46 years.

Kullerud[13] notes that in most published descriptions of iron-rich sphalerites a maximum of 2 pct unmixed pyrrhotite laths in the sphalerite is recorded. In the Broken Hill, New South Wales, Australia ore, which is believed to have been subjected to at least 600°C temperatures induced by metamorphism,[14] or by hydrothermal[8] effects, the sphalerite contains above 20 weight pct dissolved $Fe_{1-x}S$. In the laboratory Kullerud found that this content of iron was in equilibrium with ZnS as a (Zn, Fe)S mixed-crystal at 620°C and that a synthetic crystal of this composition unmixed in 28 weeks.

We are faced with this situation. Here is one of the world's largest orebodies, thought to have been at elevated temperatures for long periods. There is a high content of iron sulfide, which has a known rapid rate of diffusion, yet only 10 pct of this $Fe_{1-x}S$ content has been able to unmix from a host. Kullerud believes that traces of impurities in natural materials could slow down these processes, but it is not necessary to resort to this explanation. The following account of annealing experiments will show that these conditions of arrested diffusion in the laboratory are also present in nature.

DIFFUSION IN MULTIPLE SULFIDE SOLID SOLUTIONS

Pine Vale, Queensland

A clear discussion of the sequence of deposition and unmixing of a multiple sulfide solid solution is given by Edwards[1,8,15] for the Pine Vale copper ore from Queensland. The three main ore minerals—bornite, chalcopyrite, and tetrahedrite—occur intergrown in definite proportions of 92:7:1. The tetrahedrite occurs in oriented intergrowths of blades (Fig. 1c), forming a discontinuous lattice work pattern in the bornite; the chalcopyrite forms a similar intergrowth pattern with the bornite but has mostly unmixed to show mutual boundaries (Figs. 1a, 1b). Silver content of the tetrahedrite is uniformly high and the straight line relationship between total copper content of the ore and silver assay (1 pct Cu is equivalent to ½ oz Ag) illustrates the overall constancy of the ratio between intergrown sulfides throughout the ore from different levels in the mine.

The Pine Vale copper ore can be restored to a single solid solution if the samples are heated* for about 100 hr at 480° to 500°C. If this homogeneous solid solution is cooled from 480°C to room temperature in several minutes, the original intergrowths of chalcopyrite in bornite can be reformed. Should the time of cooling be prolonged or the sample annealed at about 250° to 300°C, the chalcopyrite diffuses rapidly outward and segregates onto the bornite grain boundaries, yielding an even-grained pattern.

The tetrahedrite lamellae redissolve in the bornite areas if the samples are annealed for about 100 hr above 285°C. Again the cooling time is critical. If the new solid solution is cooled slowly from 285°C to room temperature, the tetrahedrite reforms and then rapidly diffuses to the grain boundaries of the bornite. The process is completed in a few minutes. The original pattern of the tetrahedrite lamellae in the bornite can be preserved only if the ore samples are quenched from above 480°C to below 250°C. Any prolonged exposure to temperatures above this level will enable the tetrahedrite to diffuse outward and destroy the lattice intergrowth with the bornite. The ore in the Pine Vale veins must have been introduced at over 500°C as a single homogeneous solid solution and crystallized in its present position (while being chilled to below 250°C) in a matter of minutes. The ore minerals were introduced about 200°C hotter than the country rocks and show the present geometry of intergrown sulfides as a result of arrested diffusion.

Aberfoyle, Tasmania

Another detailed discussion[16] of the intergrowth relationships between four sulfides has recently

* Small samples (1 to 5 cc) are placed in evacuated glass tubes (Vycor high silica glass). The furnaces are controlled to ±3°C.

been published. In the tin and wolfram-bearing quartz veins of the Aberfoyle tin mine, N. E. Tasmania, several sulfide minerals occur in patches, either intergrown with cassiterite and wolframite, forming clots of sulfides in the quartz cores of the wide veins, or filling the thinner veins. The sulfides are also disseminated in the underlying aplitic granite cupola. Vugs up to several cubic inches in volume are very common in the quartz; they are partially filled with well formed crystals of all the vein minerals.

The three important sulfides—sphalerite, chalcopyrite, and stannite—occur mutually associated; each sulfide is a host containing the other two as intergrowths. Pyrrhotite is nearly always present in tiny blades exsolved from and intergrown with the iron-rich sphalerite. The three sulfides of interest total 1.0 pct of the original vein and are present in the milled ore in a sphalerite-chalcopyrite-stannite ratio of 5:4.4:1. Individual specimens are usually sphalerite-rich or chalcopyrite-rich, the former occurring in a pronounced manner in the deeper levels.[16, 17]

Each of these minerals is really a partially unmixed solid solution whose outward diffusion has been arrested by chilling. It is very significant that well formed single crystals of the sulfides (especially sphalerite) found in the vugs still show oriented intergrowths of the other sulfides when sectioned and examined under the microscope. This is similar to the *chalcoborn* crystals found at Butte, Mont., which contained intergrowths of chalcocite in a bornite matrix while preserving the external crystal form of the bornite.[18]

Since the intergrowths of these three sulfides are unusual and complex and will have bearing on the later experimental results, each natural solid solution will be described in detail.

Sphalerite: The iron-rich sphalerite, containing 13 pct Fe, occurs in the quartz veins throughout the lode, and crystals occur in aplitic granite itself and in pegmatites within the aplitic granite in the deeper levels. It is much more common in the lower levels and there becomes the dominant sulfide mineral.

Under the microscope the sphalerite is crowded with chalcopyrite and stannite, with a persistent but low concentration of pyrrhotite blades. The pyrrhotite constitutes as much as 5 pct of some intergrowths in the sphalerite, the content being slightly higher in specimens from the lowest levels in the mine. The blades are common, showing up in 25 of the 57 polished sections of the ore examined.

The chalcopyrite-sphalerite intergrowths reveal all stages of arrested unmixing. The cores of many grains are drained of fine chalcopyrite, which has segregated in parallel rows of larger blebs. This host sphalerite is blue-gray and isotropic. The edges of these grains are clouded with chalcopyrite bodies ranging from 0.001 mm down to below the limit of microscope resolution. This clouded sphalerite is more brown in color and appears strongly anisotropic, often revealing the lamellar twinning of grains that is characteristic of low-temperature ZnS. X-rays of this intergrowth show the normal patterns of sphalerite, with a pattern of included chalcopyrite, confirming that this clouded sphalerite is not wurtzite. Bands of clouding tend to follow the boundaries of grains and run parallel to transecting gangue veins. In single crystals of sphalerite from the vugs, the clouding is in narrow bands running markedly parallel to the crystal faces. Width and

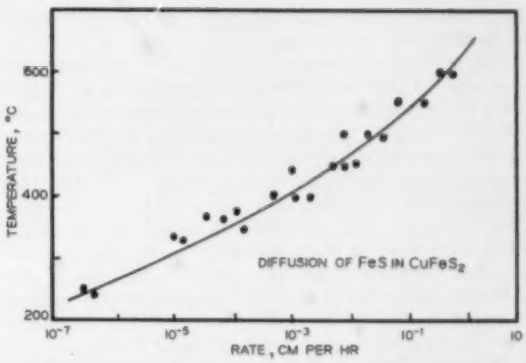

Fig. 2—Showing the diffusion velocities of FeS in chalcopyrite. Plotted in centimeters per hour in relation to the temperature. (After Borchert, 1934, Fig. 4)

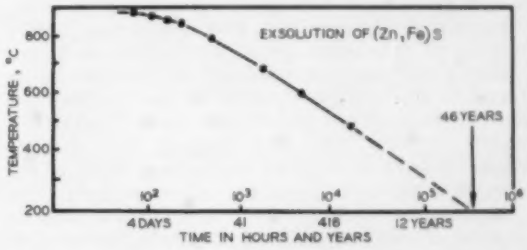

Fig. 3—Curve showing time required for complete exsolution of FeS from (Zn,F)S mixed-crystals as a function of temperature. (After Kullerud, 1953, Fig. 10.)

shape of the clouding vary from grain to grain in the ore depending upon the relative orientation of the plane of polished section to the crystal faces.

With a greater degree of segregation, the chalcopyrite has formed veinlets and in some grains has diffused out to the grain boundaries. The maximum recorded content of visible chalcopyrite in a large specimen (more than 2 sq in.) of sphalerite solid solution was 8.9 pct with an additional 11.4 pct of stannite in the same intergrown grain.

The stannite bodies appear in more clearly defined parallel rows, and have often served as nuclei for the chalcopyrite which unmixed later. Where the sphalerite is invaded by galena-matildite veinlets, the chalcopyrite segregations form a film around the margin of the galena. It is clear that the galena and matildite vein pre-dated the unmixing of the chalcopyrite from the sphalerite host solution.

Chalcopyrite: Chalcopyrite acts as a host mineral for the several other sulfides and often appears to have been the original solid solution mineral deposited in the upper parts in the veins (see later test data). Subsequent unmixing and controlled segregation of the several other intermixed solid solutions have yielded the distribution pattern of sulfides in the ore.

Sphalerite is the most common mineral intergrown with chalcopyrite. On all scales this sphalerite contains fine-grained disseminated chalcopyrite, indicating that the sphalerite itself unmixed from the chalcopyrite as a copper-bearing sphalerite solid solution rather than as a pure mineral (Fig. 6). In a large specimen of chalcopyrite 13 pct of exsolved sphalerite was measured in the form of

tiny asterisks, embayed patches, and small masses up to about 0.1 mm across.

The stannite content of the same chalcopyrite area was 16 pct but varied from specimen to specimen. As segregation of the stannite was more rapid than that of the sphalerite, stannite invariably lies on the boundaries of the chalcopyrite grains in thin curving films about 0.005 mm wide (Fig. 4). The unmixing of the stannite portion of the original solid solution with chalcopyrite, however, occurred later than that of the sphalerite, as it always surrounds the zinc sulfide. This stannite is impure and contains exsolved chalcopyrite in tiny rods and globules 0.001 to 0.01 mm long, which unmixed from a copper-bearing stannite solid solution.

Stannite: The stannite is invariably intergrown with chalcopyrite and sphalerite, any one of the three acting as host to the other two. Sphalerite occurs in the form of minute dots 0.001 mm to 0.002 mm across in the stannite, with occasional larger patches up to 0.1 x 0.01 mm which show a tendency to parallel orientation. For 0.05 mm outward from each large sphalerite patch the minute dots are absent, indicating that diffusion toward the larger areas has drained the stannite of zinc sulfide over that distance. This exact pattern of sphalerite patches, minute dots, and drained area persists without change throughout the vertical depth of the mine. In a measured specimen of stannite-rich ore the sphalerite content was 11 pct. This sphalerite contains in addition abundant small globules of

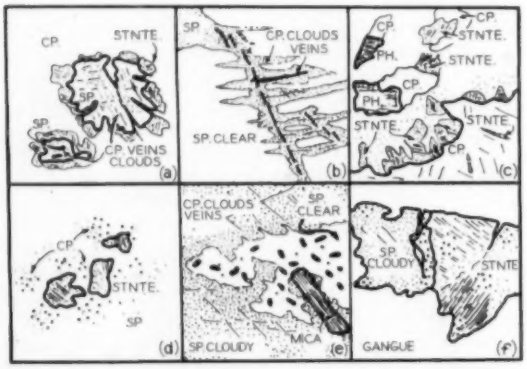

Fig. 4—Typical sulfide intergrowths in the Aberfoyle ore. Top row is from central veins (specimen used in annealing experiments). Bottom row from sphalerite clots and crystals in the aplite cupola, 300 ft below roof. X300. Micrographs reduced approximately one third. **a:** *Chalcopyrite (Cp) host; sphalerite (Sp) large exsolution patches clouded with chalcopyrite. Stannite (Stnte) molded on sphalerite and itself clouded with chalcopyrite. All stannite shows patchy inversion twinning.* **b:** *Partial unmixing of sphalerite yielding chalcopyrite clouds and veins. This sphalerite is anisotropic where clouded.* **c:** *Sphalerite host at top; chalcopyrite host in lower half. Early pyrrhotite (Ph) on which chalcopyrite and stannite are molded successively. Stannite is molded onto sphalerite-chalcopyrite boundaries, with stannite veins in the chalcopyrite.* **d:** *Sphalerite hosts, stannite exsolution patches, variable grain size of chalcopyrite blebs. In aplite cupola.* **e:** *Patch unmixing of clouded sphalerite yielding blue sphalerite and enlarged chalcopyrite blebs. Advanced stage of* (b). *In aplite cupola.* **f:** *Doublet grain of sphalerite and stannite in aplite gangue. Notice the patchy and variable clouding of the chalcopyrite in the sphalerite.*

Table I. Temperatures of Reformation of Solid Solutions, Depending on Criteria Used

	(A) Break-point of Temperature-Concentration Curves	(B) Initial Temperature of Dissolution of the Fine Threads	(C) Complete Resorption in 168 Hr
Chalcopyrite Host			
Sphalerite (solute)	400°C	550°C	700°C+
Stannite	375°C	475°C	625° to 700°C
Sphalerite Host			
Chalcopyrite	525°C	625° to 650°C	700°C+
Stannite	550°C	600° to 625°C	625° to 700°C
Stannite Host			
Chalcopyrite	400°C	475°C	Uncertain
Sphalerite	325°C	550°C	550°C

chalcopyrite which had unmixed after segregation of the sphalerite. This two-stage unmixing and segregation forms a constant pattern in the Aberfoyle ore.

Chalcopyrite is occasionally present in oriented intergrowths of rods 0.002 mm to 0.005 mm long, but most of it is in the form of veinlets crossing the stannite. Chalcopyrite of this type forms up to 4 pct of the stannite areas.

EXPERIMENTAL DATA AND RESULTS

The evidence from these detailed descriptions seems overwhelmingly in favor of origin of the intergrowths by exsolution after emplacement of the ore. The present geometry of the pattern was controlled by the arresting of diffusion. To determine the thermal history of this unmixing process, it was decided to make controlled annealing experiments of one week's duration (168 hr) at increasing temperatures until the solid solutions were reformed. This would reveal the pattern of a possible ore process.

A large specimen of typical chalcopyrite ore[18] was selected. The proportions of host mineral (solvent) and exsolved minerals (unmixed solute) were determined for each of the three solid solutions, with a Rossiwal integrating stage for the measurements. These values have been previously reported[18] and are graphed in Fig. 5.

The annealing experiments were performed by heating 2 to 5-cc fragments of this large specimen in evacuated pyrex glass tubes for 168 hr at temperatures ranging up to 700°C. After each run the tubes were quenched in cold water and the specimens repolished and remeasured for solvent and solute contents. Fig. 5 plots the changes in each of the three solid solutions with change in temperature of the annealing run.

Reformation of the Solid Solutions: Results of the annealing experiments are best summarized in Fig. 6. It should be borne in mind that the tests were conducted for only 168 hr, and Table I shows how the temperature of reformation of the various solid solutions changes with the criteria of re-solution used. These temperatures are a measure of at least two variables: 1) concentration and 2) diffusion rates of the solute in the solvent material. It is perhaps more correct to use the temperature at which the first signs of re-solution appear. A longer annealing time at this temperature will accomplish the same effects as those obtained by raising the temperature. The high temperature for re-solution of sphalerite in the chalcopyrite (700°C) is a function of its relatively slower diffusion rate, as the initial effects are apparent at 400°C.

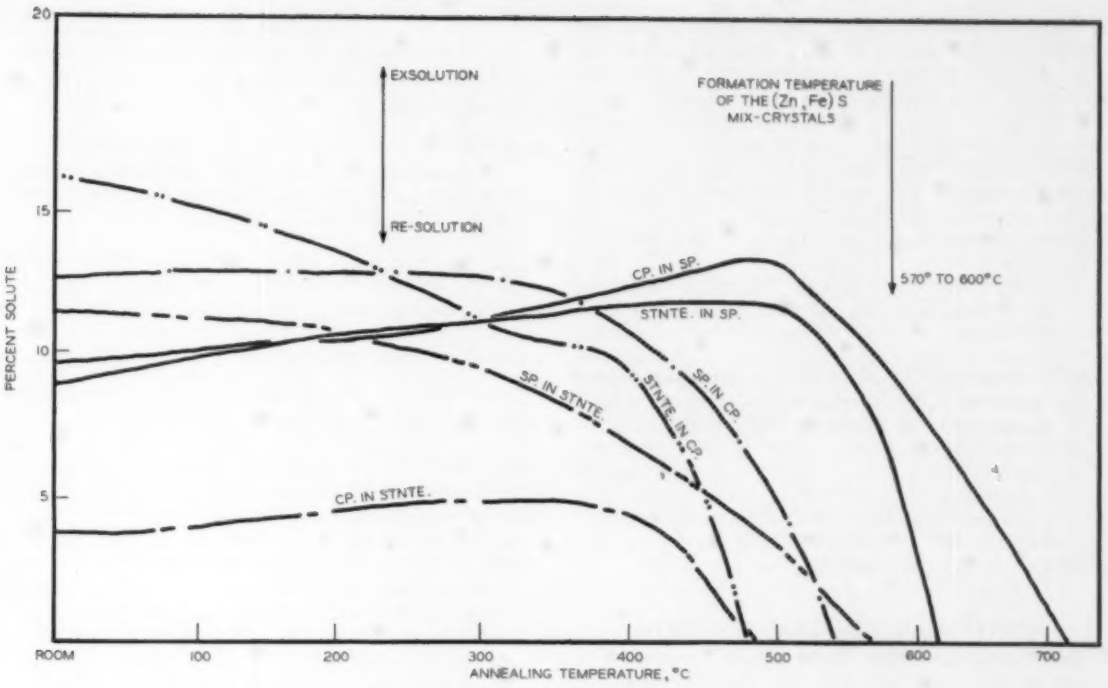

Fig. 5—Composition-temperature graph for 168-hr annealing experiments on Aberfoyle ore. Note similarity of re-solution temperatures for solid solutions and formation temperature of (Zn,Fe) mixed crystals. No pressure correction in either case. Chalcopyrite (Cp), Sphalerite (Sp), stannite (Stnte); "Stnte in Cp" is stannite content in chalcopyrite host.

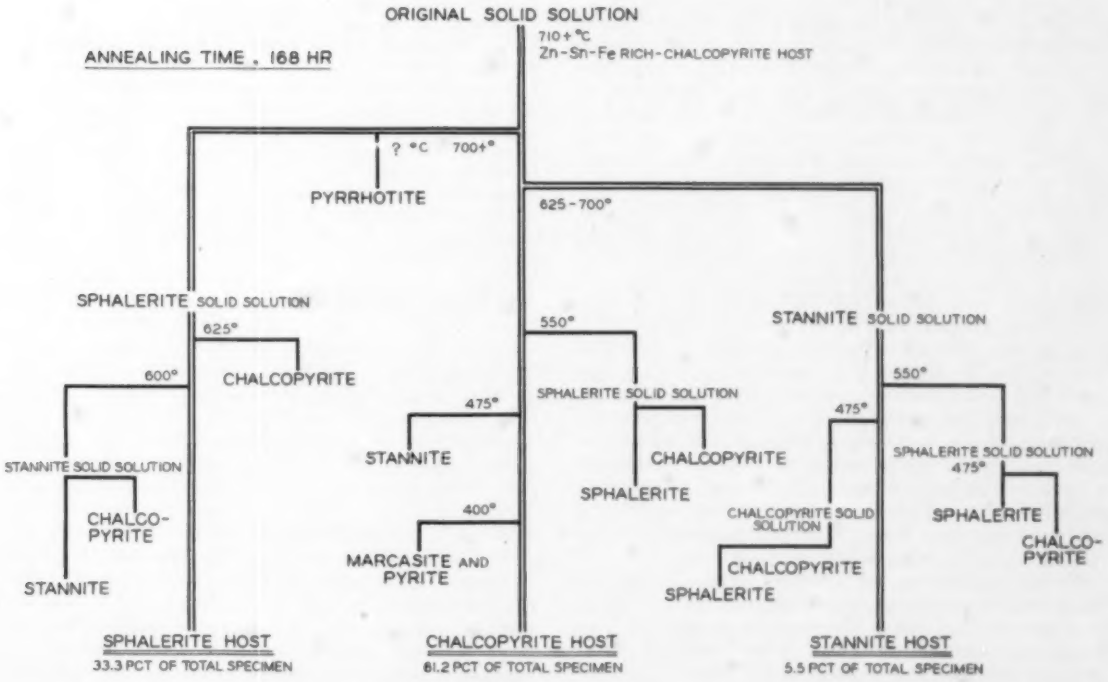

Fig. 6—Re-solution temperatures for a typical chalcopyrite-rich ore specimen. Temperatures indicate significant re-formation of solid solutions within the 168 hr of annealing, regardless of the grain size of the solute mineral.

Increased Diffusion: An interesting feature of the annealing experiments is the increased unmixing and diffusion of the chalcopyrite clouding in the sphalerite. When temperature was held at 475°C for 168 hr the clouding was intensified; more chalcopyrite was forming from the solid solution. Between 475° and 550°C this chalcopyrite segregated into enlarged patches, significantly raising the content of visible chalcopyrite (Fig. 5). Above 550°C the chalcopyrite redissolved in 168 hr until almost no trace of it remained at 700°C.

It appears obvious that the present geometry of the intergrown minerals is solely a result of arrested diffusion of several solid solutions. Given more time at temperatures higher than 325° to 400°C, increased diffusion and segregation would have removed all traces of the oriented intergrowths. Indeed the resulting even-grained granitoid texture would have indicated little of the complex thermal history. Regardless of the mechanism of ore transport, the rapid chilling of a solid solution series introduced into the veins at about 600°C appears to be the most likely way of achieving this state of suspended exsolution.

ADDITIONAL TEMPERATURE DATA

Iron Content of (Fe, Zn)S Mixed Crystal: The work of Kullerud[13] on the (Fe, Zn)S system has established a very useful geological thermometer. If the sphalerite was saturated with iron at the time of its formation, then that iron content is an indicator of the temperature of mixed crystal formation.

The Aberfoyle sphalerite on all mine levels has an iron content between 12.9 and 13.4 pct Fe. Of the 57 polished sections examined, pyrrhotite was found in a bladed intergrowth in 25, the iron sulfide covering 2 to 5 pct of the sphalerite surface. The other iron sulfides, pyrite and marcasite, occur frequently adjoining the sphalerite grains, and there is good reason to believe[14] that part of these minerals were originally pyrrhotite, either primary or exsolved from the sphalerite. This 2 to 5 pct iron sulfide is, therefore, a minimum content, and if it is assumed that the iron saturation requirements are thus satisfied, the temperature of mixed crystal formation may be calculated[13] as 570° to 600°C. This temperature apparently holds for all depths in the mine, as no significant change in the iron content can be determined. A pressure correction of 15°C for the 2000 ft of rock cover present during ore deposition can be calculated[13] which raises the deposition temperature to at least 585° to 615°C. This agrees well with the temperature of reformation of the sphalerite solid solutions (550°C) determined in the annealing experiments (see Fig. 5).

Kullerud[13] has commented upon the temperature calculated from the iron content in the Aberfoyle sphalerite, drawing attention to the very complex nature of the solid solution. Little can be done to refine these temperature data, however, until the study of this complex system is completed in synthetic form in much greater detail.

Metamorphism of the Country Rock: Thin sections over the country rock indicate that the shales and greywackes have undergone contact metamorphism sufficiently intense to develop fine-grained biotite in the matrix. It was assumed,[15] therefore, that this indicated that the country rock had not been heated over 200° to 300°C, as intense development of biotite appeared at about 400°C.[16]

SUMMARY

On the basis of experiments with ore from the Aberfoyle veins, the following hypotheses have been developed.

1) The ore was introduced at about 600°C.

Supporting Data: a) Annealing rate experiments; b) minimum figure from the iron content of sphalerite (see item 3 below).

2) Ore was introduced as a solid solution and crystallized in place before unmixing.

Supporting Data: Euhedral crystals of sphalerite from vugs show intergrowth patterns similar to those in the massive ore.

3) The solid solutions show the effects of diffusion, which has been arrested by chilling to below 325°C in a very short time. This diffusion was arrested at about 600°C (for sphalerite); all the sphalerites, therefore, contain the same amount of pyrrhotite. This proves that pyrrhotite was evenly distributed and all absorbed in ZnS, although not enough pyrrhotite was present to saturate the ZnS.

Supporting Data: a) Clouding of sphalerite varies markedly with annealing temperature (suspended exsolution); b) low grade of metamorphism of country rock, low biotite zone (200° to 300°C).

The data lead to the following conclusion:

The orebody (production total 550,000 long tons) was introduced at 600°C into a fracture zone between 100 and 1000 ft above an aplite cupola and chilled to below 325°C in a very few days.

Clearly defined data to refute this argument are hard to find. One of the points of conflict is quite significant and may hold a key to the problem:

The same pattern of complex intergrowths of the sulfides is present in the disseminated sphalerite dots in the aplite itself (300 ft beneath the cupola roof) in the pegmatite and quartz segregations, and intergrown with the wolframite as a selvage to the china-clay pipe—all in the aplitic granite cupola. It seems most unlikely that this part of the area could have been adequately cooled to freeze the diffusion of the sulfides, as all attempts to deduce the temperature gradient around an igneous intrusion[2] lead to exceedingly slow loss of heat.

It is not the purpose of this review to explain these conflicts in the data nor to propose a new theory of ore genesis. It is hoped that re-emphasizing the experimental studies will indicate the need for careful consideration of the time aspects of ore deposition as well as pressure, compositions, and temperatures of the ore fluids. Either the experimental data are incorrect by very large factors, or the classical hydrothermal theory—with its low concentrations of sulfides in aqueous solution and the implied grand expanse of time for deposition—should be critically examined. It has been assumed in these experiments, perhaps incorrectly, that the processes are reversible. It is quite possible that the position, frequency, and type of submicroscopic imperfections, defects, and dislocations in the natural crystal lattice[18] greatly influence the diffusion rates in the original deposition of the ore. Much more work must be done before these experimental data can be slavishly applied from one ore deposit

to another without very careful investigation of the ore minerals and their intergrowths.

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FACTORS AFFECTING THE CLEANING OF FINE COALS BY THE CONVERTOL PROCESS

by SHIOU-CHUAN SUN and W. L. McMORRIS III

The Convertol process was first described in Germany by Muschenborn[1] in 1952. In the U. S. Fraser[2] reported this new process in 1953, and Brisse and McMorris[3] presented the results of a Convertol pilot plant at the Alpheus preparation plant in Gary, W. Va., illustrating the mechanics of the process by a series of sketches.

The purpose of the present investigation was threefold: 1) to determine the relative effectiveness of various oils and hydrocarbons for recovering coal by the Convertol process, 2) to ascertain the behavior of coal pulps in this process under various operational conditions, and 3) to compare Convertol with flotation in the recovery of fine coals.

APPARATUS, PROCEDURE, AND COAL SAMPLES

In laboratory work with the Convertol process a Waring Blender equipped with a speed-regulating rheostat was used for wetting, conditioning, inversion, and retention of the coal pulp. A 5-in. International centrifuge was adapted to dewater the agglomerated clean coal product by installation of a 100-mesh screen inside the regular bronze basket of the centrifuge.

Except where otherwise stated, the Convertol testing was performed by the following steps:

1) A 450 to 500-cc coal slurry, containing 24 pct by weight of solids, was agitated in the blender for 10 min at 100 rpm to insure complete wetting and mixing.

2) Eight percent by weight of oil was added to the coal slurry in the blender and agitated for 1 min at 11,000 rpm to result in the phase inversion or agglomeration of oil-coated coal particles.

3) The agglomerated coal slurry was poured onto a 100-mesh sieve and wet-screened for about 2 min to remove most of the ash and some of the water.

4) The material remaining on the screen was transferred into the centrifuge for final dewatering.

5) A portion of the clean coal was immediately weighed out for moisture determination, while the

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remaining clean coal was washed with acetone to remove the attached oil and then dried, weighed, and analyzed for ash and sulfur.

6) The refuses obtained from screening and centrifuging were combined and filtered, and the resultant filter-cake was dried, weighed, and analyzed for ash and sulfur. If the conditioning and retention stages were necessary, as in the case of Fig. 6, the blender was allowed to run at 1000 rpm for both stages. For brevity, the analytical results of ash and sulfur are only selectively presented, but are available in W. L. McMorris' thesis.[4]

The three coal samples used in this investigation came from the Robena, Alpheus, and Corbin preparation plants of U.S. Steel Corp. The Robena sample was obtained from the bowl-desilter overflow of Pittsburgh Seam coal in Greene County, Pa. The Alpheus sample, representing the Pocahontas No. 3 and 4 seams in McDowell County, W. Va., was taken from the feed to a Convertol pilot plant. The Corbin sample was taken from the bowl-desilter overflow of the *B, C,* and High Splint seams coal in Harlan County, Ky. All the coal samples were shipped to the University in sealed cans to prevent undue oxidation. Size distribution and chemical composition of these samples are given in Tables I and II, respectively.

EXPERIMENTAL RESULTS

Hydrocarbons and Oils: Tests were performed to determine the relative effectiveness of hydrocarbons and oils for cleaning Robena coal slimes by the Convertol process. The results, as given in Tables III-V and Figs. 1-3, show that the agglomerating power of the tested hydrocarbons and oils on the Robena coal can be roughly predicted from their

Table I. Screen and Chemical Analyses of Coal Samples

Tyler Screen,* Mesh	Robena			Corbin			Alpheus		
	Wt, Pct	Ash, Pct	S, Pct	Wt, Pct	Ash, Pct	S, Pct	Wt, Pct	Ash, Pct	S, Pct
48 to 65	Trace	—	—	Trace	—	—	Trace	—	—
65 to 100	12.03	6.36	0.80	12.78	1.40	0.48	9.05	5.59	0.41
100 to 150	19.60	5.82	1.76	6.93	2.30	0.56	8.03	5.63	0.42
150 to 200	18.27	5.68	1.91	7.41	3.90	0.92	6.84	5.90	0.69
200 to 270	6.04	6.42	1.34	5.42	6.63	0.52	8.03	6.62	0.60
270 to 400	3.02	9.18	1.36	4.51	8.13	0.81	7.02	7.37	0.69
−400	41.04	27.74	2.45	62.95	39.94	0.44	61.03	28.79	0.76
Head	100.00	14.00†	1.80†	100.00	28.00†	0.44†	100.00	18.00†	0.56†

* Wet screen analysis. † Average.

Table II. Ultimate Analyses of Oven Dried Coal Samples

Composition	Robena, Pct	Corbin, Pct	Alpheus, Pct
Carbon	70.35	57.00	72.59
Fixed carbon	52.61	42.85	64.09
Hydrogen	4.70	3.81	4.05
Sulfur	1.80	0.43	0.54
Nitrogen	1.02	0.81	0.76
Oxygen	5.28	6.23	2.95
Volatile matter	30.54	25.43	16.80
Ash	15.85	30.36	18.54
Moisture	1.00	1.36	0.57
B.T.U.	12435	9864	11036

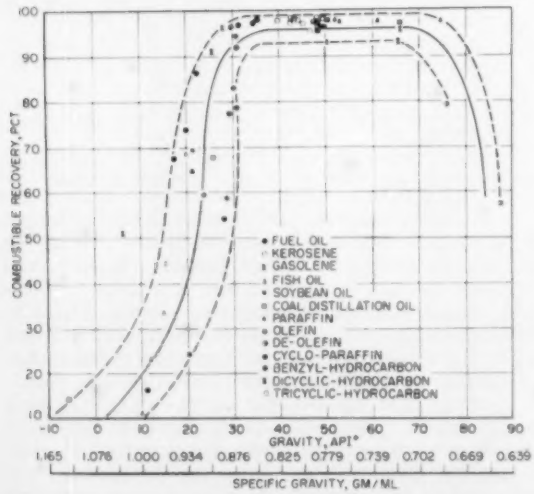

Fig. 1—Relation between specific gravity and agglomerating power of hydrocarbons and oils on Robena slime.

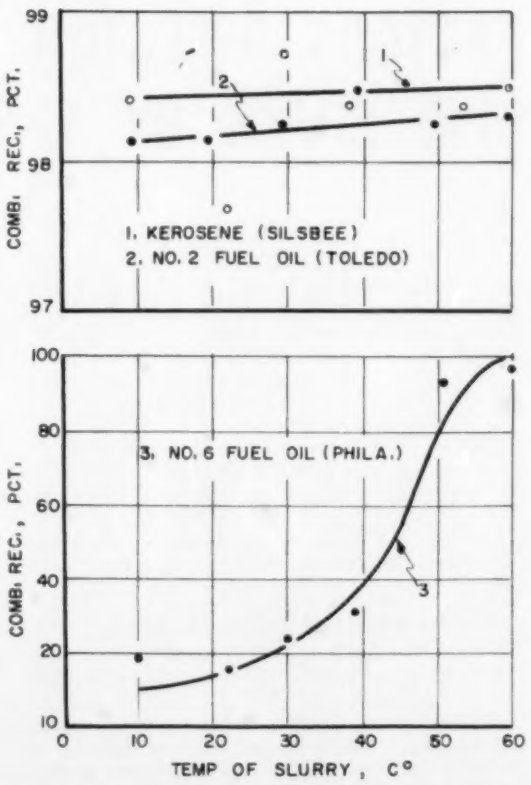

Fig. 2—Pulp temperature effects on agglomerating power of Gulf kerosene and No. 2 fuel oil on Robena slime.

Table III. Effects of Straight-Chain Hydrocarbons on Cleaning Robena Coal Slime by Convertol Process

Test Conditions: 10-min wetting, 13.5 pct pulp density, 8 pct by weight of oil, 1-min inversion at 11,000 rpm, and 1-min centrifuging at 1300 rpm.

Aliphatic Hydrocarbon								Clean Coal		
Name	Formula	Carbon Atom	Gravity API*	Sp Gr, G Per Ml	Viscosity 20°C Cp	Solu,† G Per Liter	Boiling Point, C°	Ash, Pct	S, Pct	Comb. Rec., Pct
(A) Paraffin Series										
n-Heptane	$CH_3(CH_2)_5CH_3$	7	75.3	0.684	0.409	$0.052^{18.5}$	98.25	5.30	1.69	97.23
n-Octane	$CH_3(CH_2)_6CH_3$	8	69.6	0.7036	0.539	0.015^{16}	125.8	5.38	1.71	97.50
n-Decane	$CH_3(CH_2)_8CH_3$	10	62.2	0.7301	0.907	Insoluble	174	3.62	1.70	97.68
n-Dodecane	$CH_3(CH_2)_{10}CH_3$	12	53.2	0.766	1.353^{25}	Insoluble	214.5	5.69	1.86	97.98
n-Tetradecane	$CH_3(CH_2)_{12}CH_3$	14	53.4	0.765	2.178	Insoluble	253.5	3.54	1.62	97.13
n-Hexadecane	$CH_3(CH_2)_{14}CH_3$	16	51.1	0.775	3.516	Insoluble	287.5	3.54	1.62	98.94
(B) Olefin Series										
1-Pentene	$CH_3(CH_2)_2CH{:}CH_2$	5	87.7	0.6454	0.239	Insoluble	30.1	4.44	1.38	56.95
di-iso-butylene	$(CH_3)_3C{:}CHC(CH_3)_3$	8	66.4	0.715	—	Insoluble	102.6	5.48	1.70	97.34
1-Octene	$CH_3(CH_2)_5CH{:}CH_2$	8	66.4	0.715	—	Insoluble	121.6	3.84	1.70	97.95
1-Decene	$CH_3(CH_2)_7CH{:}CH_2$	10	54.0	0.763	1.090	Insoluble	172	5.56	1.59	96.02
1-dodecene	$CH_3(CH_2)_9CH{:}CH_2$	12	51.6	0.7732	1.140^{20}	Insoluble	213	7.46	1.90	98.07
1-Tetradecene	$CH_3(CH_2)_{11}CH{:}CH_2$	14	51.1	0.775	—	Insoluble	246	5.64	1.83	98.56
1-hexadecene	$CH_3(CH_2)_{13}CH{:}CH_2$	16	49.3	0.7827	2.556^{20}	Insoluble	$158^{11.5}$	3.64	1.78	96.26
n-Octadecene	$CH_3(CH_2)_{15}CH{:}CH_2$	18	48.1	0.788	—	Insoluble	190^{35}	5.76	1.86	97.14
(C) Di-olefin Series										
Isoprene	$CH_2{:}C(CH_3)CH{:}CH_2$	5	76.4	0.6805	2.160	Insoluble	34.07	6.60	1.69	79.15

* API is the unit expressed in degree of gravity, as used by the American Petroleum Institute, and is calculated from the formula, Specific gravity = 141.5/(API + 131.5).
† Solution, solubility in water.

specific gravity. A study of Fig. 1 reveals that the specific gravity range of the highly effective hydrocarbons and oils is 0.7020 to 0.8498 or 70.0 to 35.0 API°; of the moderately effective ones, 0.6390 to 0.7019 or 90.0 to 70.1 API° at the right side of the curve and 0.8499 to 0.9658 or 34.9 to 15.0 API° at the left side; and of the non-effective ones, > 0.9658 and < 0.6390. On the basis of data in Tables III and IV it can be assumed that the large molecules of an extremely heavy hydrocarbon are too viscous to be dispersed in the coal pulp, while the small molecules of an extremely light hydrocarbon are not hydrophobic enough; thus neither can be effective in coal agglomeration. In contrast, the fluidity and hydrophobic property of a medium-weight hydrocarbon are both suitable for such a purpose. If the foregoing reasoning is accepted then some of the heavy hydrocarbons and oils might be sufficiently fluidized in a preheated coal slurry to become effective reagents. This proves to be true for the Gulf No. 6 fuel oil, as shown in curve 3 of Fig. 2. Curves 1 and 2 of the same graph show that the medium-weight oils, having enough fluidity at room temperature, are practically unaffected by preheating of slurry. Fig. 3a, however, shows that effectiveness of the No. 6 fuel oil is only slightly improved by preheating it to 110°C. It was observed that this oil was considerably more fluid at high temperatures but became viscous again when added to the slurry at room temperature.

The above classification does not lay claim to absolute accuracy, but it is sufficient as a crude rule for selecting oil. Table V shows that oils under different names and even under the same name may vary greatly in the agglomerating power on coal. While the specific gravities of oils are easily determined, or obtained from the manufacturers, their chemical compositions, boiling points, and viscosities are not. The irregularities of Fig. 1 are caused chiefly by differences among the types of hydrocarbons and oils and can be minimized by plotting each type separately.

Another series of tests determined the effects of concentration of oils on the cleaning of three different coal slimes by the Convertol process. Fig. 3A shows that with an increase in concentration of a heavy fuel oil the combustible recovery of coal increases, but after the maximum recovery is attained at the concentration of 4 pct oil, addition of more oil actually lowers recovery. This relationship is not changed by preheating the oil to 110°C. In contrast, Fig. 3B and Table VI show that the combustible recovery increases rapidly with an increase of the concentration of a medium-weight kerosene in the range of 2 to 6 pct, but a subsequent increase of kerosene results in only slight increases in combustible recovery. Fig. 3B shows also that while the concentration of kerosene is kept constant, combustible recovery of the three coal slimes tested is decreasing in the order of Robena, Alpheus, and Corbin. As can be seen from Tables I and II, these coals differ appreciably from each other not only in surface components[5] but also in size distribution and consequently have different affinities for any given agglomeration reagent.

Operational Variables: Tests were also made to determine the effects of pulp density, conditioning, inversion, retention time, and inverter speed on the cleaning of Robena coal slime by the Convertol process. Fig. 4 shows that with kerosene (Silsbee) of 0.8009 sp gr as the agglomerating reagent, the combustible recovery of coal increases rapidly with the increase of pulp density in the range of 5 to 15 pct solids, but a subsequent increase in pulp density results in only slight increases in combustible recovery. A similar relationship exists for the No. 2 fuel oil (Toledo) of 0.8477 sp gr except that the optimum pulp density is reached at 30 pct solids. The inefficiency of the low pulp density may be attributed to the relatively large distance between coal particles themselves and also between coal particles and oil droplets in the liquid phase; this lessens the frequency of collision and consequently slows the rate of agglomeration. The difference in

Table IV. Effects of Aromatic Hydrocarbons on Cleaning Robena Coal Slime by Convertol Process

Name	Aromatic Hydrocarbon: Formula	C/H Ratio	Carbon Atom	Gravity API°	Sp Gr, G Per Ml	Viscosity at 20°C, Cp	Solu.,* G Per Liter	Boiling Point, C°	Clean Coal**: Ash, Pct	S, Pct	Comb. Rec., Pct
(A) Cyclo-paraffin Series											
Methyl Cyclohexane	$C_6H_{11}CH_3$	0.5	7	48.4	0.7864	0.777^{15}	Insoluble	100.8	5.36	1.66	97.39
Trans., 1, 2, Dimethyl-cyclohexane	$C_6H_{10}(CH_3)_2$	0.5	8	50.8	0.776	0.863^{15}	Insoluble	123.7	3.66	1.69	96.31
Ethylcyclohexane	$C_6H_{11}CH_2CH_3$	0.5	8	49.0	0.784	0.838	Insoluble	131.8	4.32	1.61	96.65
(B) Benzyl Series											
Benzene	C_6H_6	1.0	6	29.4	0.8794	0.652	0.82^{20}	80.09	4.44	1.63	58.38
Toulene	$C_6H_5CH_3$	0.875	7	31.8	0.866	0.623^{15}	0.47^{15}	110.65	6.78	1.76	94.63
Ethylbenzene	$C_6H_5C_2H_5$	0.8	8	31.7	0.8669	0.691	0.14^{15}	136.15	1.65	1.65	82.78
o-Xylene	$C_6H_4(CH_3)_2$	0.8	8	30.3	0.8745	0.813	Insoluble	144.5	4.30	1.72	73.33
Styrene	$C_6H_5CH{:}CH_2$	1.0	8	24.4	0.9074	—	Very slightly soluble	146	4.80	1.46	59.39
Ethynylbenzene	$C_6H_5C{:}CH$	1.33	8	20.7	0.9295	—	Insoluble	143	2.80	1.31	24.48
Cumene	$C_6H_5CH(CH_3)_2$	0.750	9	32.0	0.864	0.73^{20}	Insoluble	152.4	4.14	1.69	91.87
Diethylbenzene	$C_6H_4(C_2H_5)_2$	0.714	10	31.9	0.8662	0.86^{20}	Insoluble	184	6.14	1.67	78.18
sec-Amylbenzene	$C_6H_5CH(CH_3)C_3H_5$	0.688	111	33.5	0.8576	—	Insoluble	192.5	5.56	1.68	96.95
Triethylbenzene	$C_6H_3(C_2H_5)_3$	0.667	12	28.9	0.8819	1.31^{27}	Insoluble	218	5.58	1.65	54.74
(C) Dicyclic Series											
decahydronaphtalene	$C_{10}H_{18}$	0.556	10	26.4	0.8963	3.381	Insoluble	194.6	3.80	1.63	91.30
Methylnaphthalene	$C_{10}H_7CH_3$	1.1	11	6.5	1.025	3.33	Insoluble	244.8	3.18	1.46	51.53
Dicyclohexyl	$CH_2(CH_2)_4CH\text{-}CH(CH_2)_4CH_2$	0.545	12	28.4	0.8848	4.027	Insoluble	238.5	5.40	1.62	96.71
(D) Tricyclic Series											
Fluorene	$C_6H_4CH_2C_6H_4$	1.3	13	23.0	0.916	—	Insoluble	298.0	—	—	None†

* Solu., solubility in water.
** Test conditions were same as that of Table III.
† No phase inversion.

Table V. Effects of Various Commercial Oils on the Cleaning of Robena Coal Slime by Convertol Process

Test No.	Oil: Name and Source	Gravity API°	Sp Gr, G Per Ml	Clean Coal*: Ash, Pct	S, Pct	Moisture, Pct	Comb. Rec., Pct
1	Fuel oil,[a] No. 2, (Toledo)	35.9	0.8477	5.86	1.70	13.5	98.13
2	Fuel oil,[a] Dieselect	35.6	0.8468	6.06	1.91	13.5	97.09
3	Fuel oil,[a] No. 2, (Port Arthur)	32.1	0.8649	6.44	1.90	12.0	96.65
4	Fuel oil,[a] Cracked No. 2	23.0	0.9195	5.84	1.86	11.0	88.62
5	Fuel oil,[a] No. 4, (N. Y.)	20.3	0.9321	5.61	1.62	12.2	74.07
6	Fuel oil,[a] No. 5, (Philadelphia)	18.0	0.9493	5.54	1.64	14.3	67.57
7	Fuel oil,[a] No. 6, (Philadelphia)	11.5	0.9895	5.38	1.77	10.5	16.00
8	Kerosene, (Mexico)	49.6	0.7814	5.32	1.81	16.5	98.22
9	Varsol,[b] (Canada)	50.3	0.7784	5.07	1.78	16.3	98.16
10	Kerosene,[b] (Canada)	44.6	0.8036	4.84	1.73	14.3	97.77
11	Kerosene,[a] (Silsbee)	45.2	0.8009	4.97	1.73	14.5	97.66
12	Kerosene,[a] (Venezuela)	40.4	0.8229	4.99	1.73	16.4	97.65
13	Kerosene,[a] (Houston)	43.3	0.8094	5.18	1.72	20.1	97.58
14	Kerosene,[c] (Norco)	43.9	0.8069	4.95	1.77	16.3	97.52
15	Kerosene,[a] (Port Arthur)	46.1	0.7967	5.92	2.06	12.5	97.11
16	Kerosene,[d] purified	47.8	0.7891	5.22	1.62	16.7	95.44
17	Gasoline,[e] imperial	67.1	0.7124	7.52	—	18.7	96.90
18	Gasoline,[e] regular	66.0	0.7164	7.76	—	19.2	93.50
19	Coal tar naphtha[f]	25.7	0.9000	7.45	1.91	16.0	67.87
20	Heavy creosote[f]	−6.3	1.13	4.88	1.55	15.7	14.48
21	Soybean oil,[g] white refined	21.6	0.9240	4.28	1.60	16.8	69.68
22	Soybean oil,[g] degummed raw	21.6	0.9240	4.86	1.68	13.5	64.77
23	Fish oil,[h] light, cold pressed	20.4	0.931	5.10	1.66	12.5	68.74
24	Fish oil,[h] crystol L	15.7	0.961	4.56	1.59	15.6	44.30
25	Fish oil,[h] crystol W	15.0	0.966	2.90	1.35	18.7	33.05
26	Fish oil,[h] Blown No. 3	12.2	0.985	5.26	1.44	18.7	22.36
27	Fish oil,[h] Blown No. 6	10.0	1.000	—	—	—	none†

Source: a, Gulf Research and Development Co., Pittsburgh, Pa.; b, Imperial Oil Co., Canada; c, Shell Oil Co., New York; d, local ESSO station; e, local Atlantic station; f, Koppers Co. Inc., Pittsburgh, Pa.; g, General Mills Inc., Kankakee, Ill.; and h, Archer-Daniels-Midland Co., Cleveland, Ohio.
* Test conditions were same as that of Table III, except that the pulp density was 24 pct.
† No phase inversion.

Table VI. Effects of Concentration of Gulf Kerosene (Silsbee) on Cleaning Robena, Alpheus, and Corbin Coal Slimes by Convertol Process

Test Conditions: 10-min wetting, 24.25 pct solids,
1-min inversion at 11,000 rpm and 1-min centrifuging at 1300 rpm

Kerosene, Wt, Pct	Robena Clean Coal: Ash, Pct	S, Pct	Yield, Pct	Comb. Rec., Pct	Alpheus Clean Coal: Ash, Pct	S, Pct	Yield, Pct	Comb. Rec., Pct	Corbin Clean Coal: Ash, Pct	S, Pct	Yield, Pct	Comb. Rec., Pct
2	7.72	1.71	60.48	65.21	5.99	0.66	70.30	81.09	4.89	0.57	53.10	72.20
4	6.02	1.67	86.40	93.01	5.14	0.62	79.50	91.21	4.83	0.56	67.60	89.72
6	6.50	1.71	89.12	97.77	5.50	0.64	83.90	96.55	4.60	0.56	71.20	94.42
8	4.97	1.73	89.68	97.66	5.99	0.64	85.00	97.37	4.34	0.56	71.90	96.06
10	6.16	1.74	91.52	98.47	6.00	0.68	87.60	98.25	4.61	0.53	75.30	96.28

optimum pulp density between kerosene and fuel oil may be explained by the fact that kerosene is lighter and consequently less viscous and more dispersible than fuel oil, so that it can produce more oil droplets for collision with the widely dispersed coal particles in a relatively dilute pulp of 15 pct solids.

Fig. 5A shows that efficiency of the kerosene is only slightly improved by conditioning, prior to phase inversion, for 2 min or longer at 1000 rpm, whereas the effectiveness of the fuel oil is practically unchanged by conditioning. It can be deduced from Fig. 5B that the Robena coal is effectively coated and agglomerated by either of these two oils during the 1-min phase inversion at 11,000 rpm and consequently requires no conditioning. For the same reason, retention is not needed either, as indicated in Fig. 5C. Fig. 5B shows also that the optimum time for phase inversion, at a speed of 11,000 rpm, is 1 to 2 min. With less than 1 min, the coal particles are not sufficiently coated by oil for complete agglomeration. With more than 2 min, the large coal agglomerates are gradually disintegrated by the tearing force of eddying currents

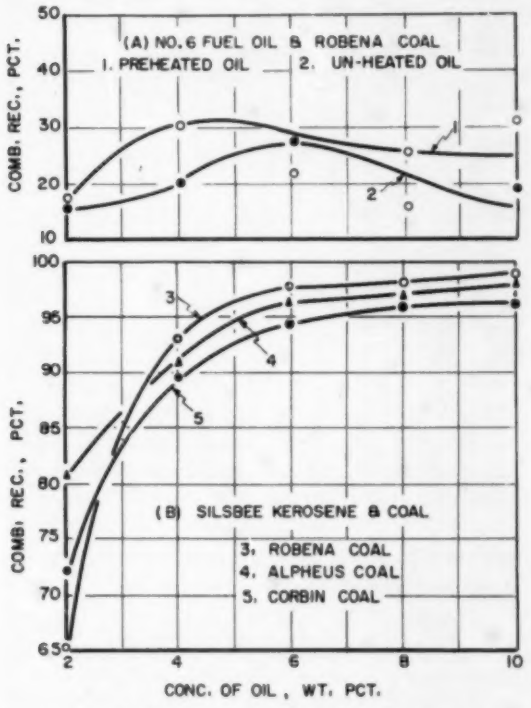
(A) NO. 6 FUEL OIL & ROBENA COAL
1. PREHEATED OIL
2. UN-HEATED OIL
COMB. REC., PCT.
(B) SILSBEE KEROSENE & COAL
3. ROBENA COAL
4. ALPHEUS COAL
5. CORBIN COAL
CONC. OF OIL, WT. PCT.

Fig. 3—Graph shows the effect of concentration of oils on the cleaning of coal slimes by the Convertol process.

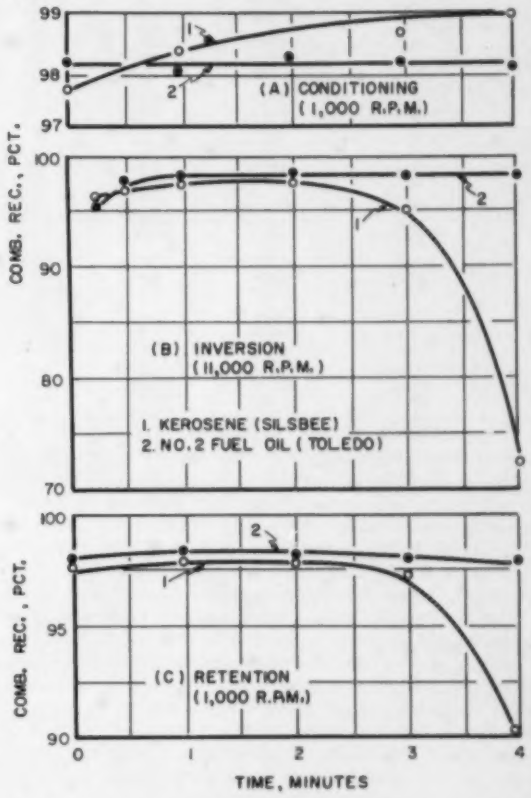

Fig. 5—Effects of conditioning, inversion, and retention time on cleaning Robena slime by Convertol process.

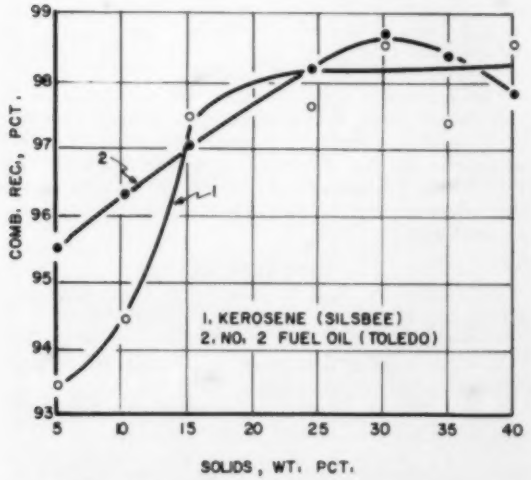

Fig. 4—Graph shows the effect of pulp density on the cleaning of Robena coal slime by the Convertol process.

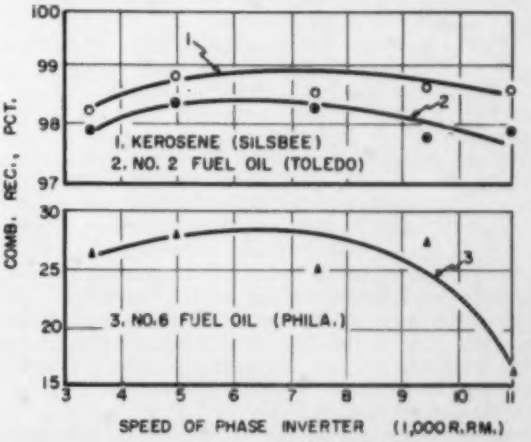

Fig. 6—Graph shows the effects of inverter speed on the cleaning of Robena coal slime by Convertol process.

Table VII. Rougher Flotation of Robena and Corbin Coal Slimes in Laboratory Fagergren Machine at pH 7.5

Test No.	Product				Comb. Rec., Pct	Reagent, Lb Per Ton			Flotation Time, Min
	Name	Wt, G	Ash, Pct	S, Pct		Silsbee Kerosene	Yarmour F Pine Oil	Carbinol*	
1	Robena	265.4	13.99	1.73	100.0				
	Conc.	130.4	8.48	1.72	99.0			0.14†	6
	Tail	15.0	98.80	1.91					
2	Robena	267.0	13.30	1.82	100.0				
	Conc.	240.5	8.70	1.80	94.9		0.14†		6
	Tail	26.5	55.17	2.00					
3	Robena	274.0	14.31	1.92	100.0				
	Conc.	261.0	10.84	1.91	99.2		0.53†		5
	Tail	13.0	86.68	2.12					
4	Robena	239.0	13.80	1.87	100.0				
	Conc.	220.0	9.24	1.85	96.9	0.33†	0.14		6
	Tail	19.0	66.25	2.10					
5	Robena	267.5	15.12	1.80	100.0				
	Conc.	246.5	9.56	1.78	98.2	5.35†	0.14		5
	Tail	21.0	80.90	2.04					
6	Corbin	202.7	10.51	0.82	100.0				
	Conc.	195.0	7.34	0.81	99.7			0.18†	4
	Tail	7.7	93.00	1.08					
7	Corbin	214.8	15.24	0.66	100.0				
	Conc.	199.6	11.38	0.66	97.1		0.18†		4
	Tail	15.2	65.76	0.92					
8	Corbin	155.4	27.91	0.70	100.0				
	Conc.	122.4	9.92	0.59	98.6		0.48†		4
	Tail	33.0	95.10	0.97					
9	Corbin	196.5	11.12	0.90	100.0				
	Conc.	186.0	7.34	0.89	98.7	0.84†	0.18		4
	Tail	10.0	78.61	0.91					
10	Corbin	201.0	10.10	0.83	100.0				
	Conc.	194.0	7.44	0.82	99.2	1.67†	0.18		4
	Tail	7.0	83.31	0.93					

* Methyl isobutyl carbinol. † Conditioning for 3 min.

and by the disruptive force of collision. The disintegration of coal agglomerates formed by kerosene is much more than that formed by fuel oil. This is probably due to the fact that coal particles are more easily dislodged from kerosene than from fuel oil, since kerosene is less viscous and more volatile. Fig. 5C shows that coal agglomerates also start to disintegrate after 2 min of retention.

Fig. 6 shows that the optimum speed of the phase inverter (Waring Blender) for a 1-min agglomeration of Robena coal slime with 8 pct by weight of kerosene, No. 2 fuel oil or No. 6 fuel oil, is 5000 to 7000 rpm. Efficiency is somewhat lower on either side of this range. The relatively weak agitation resulting from speeds lower than 5000 rpm is insufficient for effective mixing of coal and oil. Conversely, the violent turbulence resulting from speeds higher than 7000 rpm is capable of disintegrating the coal agglomerates.

Flotation: Table VII shows that both the Robena and Corbin coal slimes can be easily cleaned by flotation with methyl isobutyl carbinol, pine oil, or a combination of kerosene and pine oil as the reagent. Of the flotation reagents tested, methyl isobutyl carbinol is the most effective. Comparison of Tables VI and VII shows that the Convertol process is superior to rougher flotation in lowering the ash content of these two particular coal slimes. It is expected that flotation effectiveness will be improved by the inclusion of a cleaning circuit and/or by addition of a suitable depressant, although no such experiments were performed. Noteworthy also is the fact that flotation requires a much smaller amount of reagent than the Convertol process. However, it has been pointed out by other investigators[6] that the Convertol process can be economically justified for recovering metallurgical coal because the oil in the product is beneficial to coke plant operations. Selection of either method will depend upon the special conditions of each company and the ultimate use of the clean coal.

SUMMARY

1) A crude rule is established for selecting oils in the cleaning of coal slimes by the Convertol process.

2) The optimum pulp density ranges from 15 to 30 pct solids, depending on the oil used. The optimum time for phase inversion, at 11,000 rpm, is 1 to 2 min. Optimum inverter speed is 5000 to 7000 rpm.

3) Neither the conditioning or the retention stage is needed if the coal slurry is properly treated in the inversion stage.

4) The Convertol process and flotation are both effective for cleaning the Robena and Corbin coal slimes.

The writers are indebted to the coal division of U.S. Steel Corp. for furnishing the coal samples. They wish to thank P. D. Rao and D. J. Cook for assistance in the flotation experiments, and they also express appreciation to D. R. Mitchell and H. B. Charmbury for their encouragement and helpful criticism.

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Agglomeration Will Be Theme of International Symposium in 1961

Plans are progressing for the International Symposium on Agglomeration sponsored by the Metallurgical Society, the Society of Mining Engineers and the Society of Petroleum Engineers of AIME. Although the date seems far away, April 12 to 14, 1961, arrangements are already in the works, with the Hotel Sheraton in Philadelphia as headquarters.

General conference chairman is W. B. Stephenson of Allen-Sherman-Hoff Pump Co. It is his job to coordinate the committees and develop a smoothly run conference. To assist him in symposium planning he selected an advisory committee of representatives from the sponsoring Divisions. Kempton H. Roll will represent the Institute of Metals Division; and F. M. Hamilton will represent the Iron & Steel Division on the advisory board. A. Y. Bethune will give advice representing the Extractive Metallurgy Division; T. B. Counselman of the Minerals Beneficiation Division, and C. F. Clausen of the Industrial Minerals Division, complete the advisory board. Mr. Stephenson will call upon these men to render decisions on problems of basic policy nature.

The meeting will not be limited to studies of sintering and pelletizing ore. A direct appeal will be made to those concerned with sintering of lead, zinc, and copper ores. The symposium will also encompass the agglomeration of non-metallics, industrial minerals, and carbonaceous materials. Consideration will also be extended powder metallurgy aspects of agglomeration, both ferrous and non-ferrous.

As to approach, basic process mechanisms common to agglomeration processes in general will be considered. Thus, the meeting will be more theoretical than applied. Detailed descriptions of operations will be included only if a specific purpose is to be served. The program will be comprehensive, beginning with size distribution of materials to be agglomerated and concluding with the utilization of agglomerated products.

With the approval of the advisory council, Mr. Stephenson selected committee chairmen to do the actual work of the conference in its various aspects. Dwight C. Brown was chosen as program committee chairman, and his list of appointees from each Division is now complete and ready to go to work. The list includes M. E. Volin, MBD; R. E. Lund, EMD; R. W. Smith, Ind MD; L. L. Seigle, Inst.M.; and T. L. Myron of I & S. These men will be responsible for selecting papers and authors, planning the sessions, nominating session chairmen, and arranging plant visits.

The first meeting of the program committee took place in Chicago, November 3.

J. B. Wagstaff of the publications committee will be in charge of the preprinting of technical papers, their distribution, and the publication of the Symposium Proceedings.

Finance chairman B. J. Larpenteur will be responsible for registration, fees, and other financial arrangements.

The arrangements committee under chairmanship of W. F. Rappold, and with the assistance of H. N. Appleton (AIME Convention Manager), has already started work on hotel reservations. Further plans will be carried out to arrange for meeting rooms, publicity, transportation, social activities, and a ladies program.

It is not too early to start meeting plans, for the wheels are turning to produce a worthwhile international symposium.

Pacific Northwest To Discuss Gold in 1960

An all-day session on gold, headed by nationally and internationally known figures in mining, banking, and finance will be one of the main features of the Pacific Northwest Regional Conference to be held in Portland, April 28 through 30.

This session has already attracted considerable interest not only in mining circles but among bankers as well. Donald H. McLoughlin, president of Homestake Mining Co., and AIME President in 1950, will be a member of the *Panel of Experts* which will discuss the economic and monetary aspects of gold at domestic and international levels.

Three major refractories manufacturers will present papers at the *Refractories for the Aluminum Industry* session scheduled for Thursday. A paper on the new electron beam furnace used in the purification of columbium and tantalum, and one on the Strategic-Udy Process have been secured for the two-day metallurgy session.

Special attention is being given to wives of delegates attending the conference, which will be held in the brand new Sheraton Hotel. In addition to the specialty shops in the hotel itself, there will be tours to the Lloyd Shopping Center nearby which is nearing completion and will be the largest of its kind in the country. A bus tour of the city, a luncheon, and a special evening at the Portland Art Museum are also planned.

For further details, write to Ralph S. Mason, publicity chairman, 1069 State Office Bldg., Portland 1, Ore.

CEREMONIES MARK GROUND BREAKING FOR UET CENTER

Breaking the ground together, the Honorable Herbert Hoover and Jerry Fujimoto, freshman engineering student from Hawaii, mark the start of the new United Engineering Center, while Andrew Fletcher, UET president, smiles proudly.

Ground breaking ceremonies for the United Engineering Center were held on October 1 in New York. Former President Herbert Hoover, representing the older generation of engineers, shared the earth-turning honors with a freshman engineering student from Hawaii, Jerry Fujimoto, who represented the engineers of the future.

The 18-story structure to be erected opposite the United Nations between 47th and 48th Streets will be the headquarters of 18 major engineering societies with a combined membership of more than 300,000. These societies are responsible for a major part of the nation's technical publications, industrial standards, and engineering conferences.

Mr. Fujimoto, an American citizen of Japanese extraction, enrolled this fall at Rensselaer Polytechnic Inst. He is a member of the newest engineering class in the oldest engineering college in the country from the newest state in the Union. His home town is Waipahu on the island of Oahu.

Several thousand people were invited to the ceremonies, including many representatives of foreign engineering groups. Major excavation began later in the month, with completion scheduled for mid-1961. Plans for the Center have been over eight years in the making. The campaign for funds has received nearly $5 million in contributions from industry and $3 million from individual engineers.

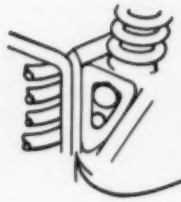
Andrew Fletcher, president of United Engineering Trustees, the organization that will own and operate the structure on behalf of the engineering societies, declared that "the primary purpose of the new structure is to provide adequate working space for the headquarters staffs of the engineering groups, which carry on extensive publishing, research and standardization programs." The second purpose, he added, "will be to symbolize the growing strength and growing unity of the engineering profession."

Perhaps significant of the active role played by AIME is that both the Honorable Herbert Hoover, who was the ground breaker, and current UET president Andrew Fletcher are former AIME Presidents.

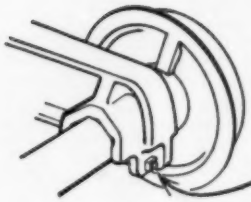
Mervin J. Kelly, chairman of the Industrial Building Fund Campaign, and retired president of Bell Telephone Laboratories Inc., was one of the speakers at the ceremony. He stated that "This happy occasion provides opportunity for public acknowledgment and thanks to the more than 500 corporations and 56,000 engineers and friends of engineering, whose contributions have been in size sufficient to warrant our proceeding with the construction of the Center . . . As generous as has been the response, as yet, we do not have pledged all funds required for a Center free and clear of debt encumbrance. . .

"The continued existence of our society of free men is now threatened as never before. An intimate picture of this threat, its character, dynamics and strength has been recently brought forcefully to our attention in the many public utterances of Premier Khrushchev while visiting our country. He stressed Communism's ultimate burial of our system through greater economic strength made possible by its greater dedication to and growing power in science and engineering.

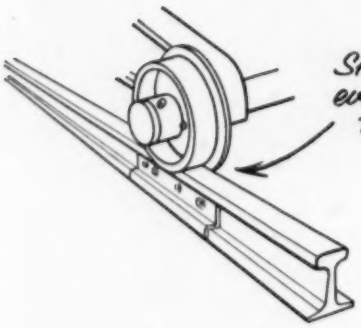
"The New Center that will rise on this site will make a large contribution to proving Mr. Khrushchev wrong."



Movement between bolster and side frame is taken on specially designed wear surfaces



Quick wheel change



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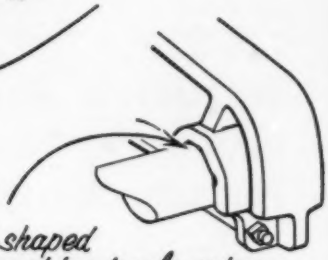
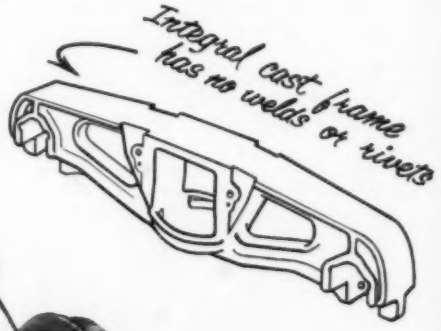
Large center bearing for longer life



V-shaped machined axle grips for controlled flexibility and truck alignment

Integral cast frame has no welds or rivets



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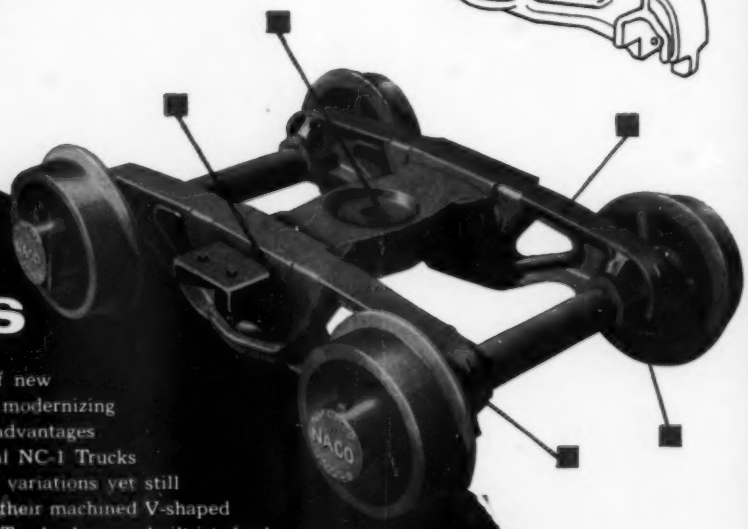

If you're considering the purchase of new 8-wheel mine cars . . . or if you're thinking of modernizing older cars—*now* is the time to check the advantages of National NC-1 Trucks. National NC-1 Trucks have controlled flexibility for track variations yet still maintain truck alignment through their machined V-shaped axle grips. In addition, NC-1 Trucks have a built-in shock absorbing mechanism.

You get more out of your mine car investment per workshift . . . per day . . . per year. And at the same time you minimize spillage . . . get greater protection for your equipment, track and structures . . . slash maintenance to a new low.

Yes, *now* is the time to check National NC-1 Trucks—they make sense for 8-wheel mine cars . . . *make dollars for operators*, too.

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ROCK IN THE BOX

Mining & Exploration Division

DIVISIONAL ANNUAL MEETING PROGRAM TAKES FINAL SHAPE

Ten sessions have been set for the 1960 Annual Meeting in New York as the Mining and Exploration Division's share of the year's major mining technical meeting.

As now planned the ten sessions are distributed as two on open pit mining, two on underground mining, a geophysical session, a geochemical session, two on geology, an SEG session, and a session devoted to the Jackling Lecture.

Open Pit Mining

The first session on Monday morning covers accident prevention, use of automatic computers, rock dynamics, and portable crushers in pit operation.

The second session on Tuesday morning is devoted to various aspects of rock behavior, under stress, on slopes, and to true rock tensile strength. Ample time is planned for questions and discussion.

Underground Mining

Monday afternoon the first session will be devoted to mine plant and mechanization design for both small and large operation. The second session on Wednesday morning will provide operating reports in detail from a new property in Canada and from El Salvador, Chile's newest copper producer.

As in the case of Open Pit Mining the chairmen are stressing ample time for both presentation, discussion, and questions.

Geochemistry

Carbon in soils, status of Russian geochemical prospecting, application of geochemistry in the preCambrian shield of Canada, and copper solubility are among the topics slated for discussion on Monday morning. Co-charimen are F. C. Canney and D. R. Cook.

Geophysics

Airborne gravity measurement, resistivity surveys, airborne AFMAG surveys, and IP and EM surveys are among the topics in the five papers listed for the session on Monday afternoon. R. K. Waring and B. F. Howell, Jr., are the co-chairmen.

Geology

The first of the two Geology sessions will be on Thursday morning. Four papers from different areas will be covered under the broad session topic "Contributions of Geology to Operating and Exploration Problems." The second session will be held that afternoon on the topic, "Iron Ore Geology." Four papers are listed for this second session including ones from Canada and the Mesabi. F. G. Pardee and Ralph Marsden are co-chairmen.

SEG

The Society of Economic Geologists will present a full session on Tuesday morning under the chairmanship of Robert Grogan.

Jackling Lecture

The Jackling Lecture will be presented by Dr. Louis B. Schlicter and will be followed by one paper on Operation Plowshare. Title of the Jackling Lecture is "Need For a New Philosophy for Prospecting."

EDITOR

Address news items to:

John W. Chandler, American Metal Climax Inc., 61 Broadway, New York 6, N. Y.

Nagle PUMPS ARE A COMFORT TO HAVE

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One of ten Nagle 2" type "QW-B," vertical shaft, centrifugal pumps is pictured recirculating spillage to a concentrator at the Paragsha Copper Concentrating Plant of Cerro de Pasco Corp., in Peru. Pump is suspended from chain hoist between guide rails for easy raising and lowering. Fifteen Nagle pumps used at this plant.

The "QW-B" is a wet pit pump with shaft bearings enclosed in a quill. It is as efficient, foolproof and free of maintenance as a pump can be —a good pump to have when you're far from the source of supply. Like all Nagle Pumps, the "QW-B" is designed for abusive service—to handle abrasive or corrosive mixtures, slurries, not liquids. There's a Nagle horizontal shaft or vertical shaft pump for every abusive pumping job. Ask for Catalog 5206.

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H. H. Lowry Honored by Percy Nicholls Award

H. H. LOWRY

The Percy Nicholls Award, a joint honor of AIME and ASME, was presented this year to Homer Hiram Lowry of Wilberding, Pa., "in recognition of outstanding achievement in the field of solid fuels."

Distinguished in the field of the chemistry of coal utilization, Dr. Lowry, who is a consultant, received the award the evening of October 28, at the banquet of the 22nd Annual Joint Fuels Conference in the Netherland Hilton Hotel, Cincinnati. The Conference was sponsored by the Coal Division of AIME and the Fuels Division of ASME, in cooperation with the AIME Ohio Valley Section and the ASME Cincinnati Section.

The citation, describing Dr. Lowry as "an exceptionally fine scientist, leader, and a very worthy, yet modest gentleman," also declares "He has made outstanding contributions to the science and technology of coal and its utilization which have benefited all mankind. A prolific writer, Dr. Lowry is the chief architect of the monumental two-volume book on *Chemistry of Coal Utilization*, sponsored by the National Research Council. This book is a recognized classic and provides source material for the solution of many technical problems encountered in the utilization of coal."

Plan Your Vacation For Caribbean Sun and Sea

It's time to dream of sunny isles and balmy days that fill the post-convention vacation program for every lucky AIME member. The weather in the West Indies during February is most delightful, a welcome contrast to the chill of New York where the Annual Meeting will be held. Warm sunshine, cloudless skies, and the brilliant blues of the Caribbean are waiting for those who make their plans now for the week of Feb. 19 to 25, 1960.

In order to make this program available to as many AIME members as possible, it is offered with a choice of three itineraries. The first includes Ciudad Trujillo in the Dominican Republic for seven days at the bargain cost of $298.50 per person. The second trip continues to San Juan and Ponce, Puerto Rico, for eight days and a total cost of $396.50 per person. Finally, trip number three includes the Dominican Republic and Puerto Rico and adds the Virgin Islands, with a stop at St. Thomas, for eight days and $436.50 per person. So everyone may go to the Dominican Republic, some will see Puerto Rico, and a few more will include the Virgin Islands. All who go will enjoy the sun and sea of these southern isles.

The arrangements are based on modified American Plan (breakfast and dinner throughout) and include round-trip tourist air transportation from New York. The hotels are the finest in the international luxury category. They include The Embajador Intercontinental in Cuidad Trujillo; The Ponce Intercontinental at Ponce; and Bluebeard's Castle in St. Thomas.

For additional details regarding rates and other features, write to Theilig International Tours, Daily News Plaza, Suite 2111, Chicago 6, Ill.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► Both the Henry L. Doherty Memorial Fund and Seeley W. Mudd Fund Committees have approved charging the cost of the *Petroleum Conservation Volume* to the Henry L. Doherty Memorial Fund, with an appropriate bookplate indicating the donor. The volume will be distributed free to new Junior Members on request. Like the Seeley W. Mudd fund, the Henry L. Doherty fund will now support the free distribution of AIME books to new Junior Members on request.

► L. E. Shaffer, chairman of the Council of Education, has appointed S. D. Michaelson as contact director on the AIME board of directors for the Council of Education in 1959.

► W. R. Hibbard, Jr., was appointed to succeed John P. Nielsen on the

(Continued on page 1167)

Student Venture Views Mining As A Career

The decrease in enrollments in mining, metallurgical, and petroleum engineering schools has caused a great deal of concern for the future of the minerals industry. The 29 accredited mining schools, for example, graduated only an average of 7.6 engineers in 1957-1958. At this depressed state freshman enrollments in the fall of 1958 declined another 16 pct below senior enrollments. Those who are disturbed by these statistics realize that the lack of interest in mining careers often stems from lack of information and dramatic experience that would entice young students to enter the mining field. They have begun to take action at the high school level, where the direction of future study is often determined.

One effort to dramatize for the young students the challenges of the engineering life is the newly established program of the Woman's Auxiliary of AIME. Called the Pilot Student Venture last year, renamed and expanded into the *Engineers for Tomorrow* program this year, the project enlists the cooperation of universities and industry in presenting a picture of mining life to high school students. Four groups of 12 students each visited four universities and numerous mining operations for a week of general engineering training and experience. Those interested in furthering the coal industry should promote activities similar to these trips to stimulate the interest of future mining engineers. The WAAIME program is described on page 1168.

Pennsylvania State University welcomed the high school students for a week in June, under the direction of Howard L. Hartman, head of the mining department. On the first day the students toured the campus and were dinner guests of the Central Pennsylvania Coal Producer's Assn. Mining movies and discussion of the mineral industries completed the day's schedule.

The surface coal mining operations of Clearfield county were visited the following day, under the supervision of the Central Pennsylvania Open Pit Mining Assn. The students also toured preparation plants and reforestation area, before a Rotary dinner at Hotel Phillips in Phillipsburg, Pa.

Underground, surface, and preparation plants were studied on the third day at the Colver properties of Eastern Gas & Fuel Assocs., Ebensburg, Pa.

The Warner Co. Bell Underground Limestone mine at Bellefonte, Pa., plus the lime and surface plants were part of the program on the fourth day. The guests also saw the College of Mineral Industries and Department of Mining, as well as enjoying a picnic and swimming at Whipples State Park.

On the final day they toured the Joy laboratory and experimental mine at Saltsburg, Pa. and the Joy plant at Franklin. The boys were overnight guests of Joy with industry representatives joining them for dinner to answer final questions and help summarize their experiences.

At the Virginia Polytechnic Inst. Charles T. Holland was in charge of the group. The boys spent the first day traveling to Blacksburg from Charleston, W. Va. with a conference on the tour after dinner. The next day they went to Plasterco, Va. to visit the U. S. Gypsum Co. underground mine and mill.

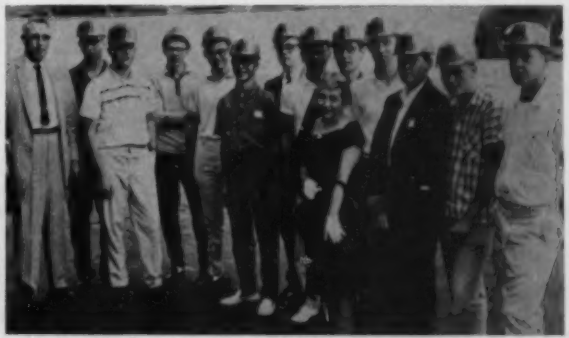
They saw the New Jersey Zinc Co. at Austinville, Va., the next day, and the Pocahontas Fuel Co. at Itman, W. Va. the fourth day.

After seeing these various operations, the boys spent a day on campus visiting laboratories, listening to lectures, and swimming at Mountain Lake. A banquet in the faculty dining center climaxed the program, with a final question and answer period the next morning before departure.

G. Ralph Spindler led the group as he did last year at West Virginia University. Mineral industries films and discussions, an introduction to geophysics and seismology, and the

(Continued on page 1164)

The Pennsylvania State University group is on location at the Colver mine of Eastern Fuel & Gas Assocs. along with industry men as guides. See page 1168 for more news.



Dean G. Ralph Spindler, E. J. Sandy, and Claude Goode are seen at left with the West Virginia University group of visiting students. S. Earhart, high school science teacher, acted as counselor. On the right the Virginia Polytechnic Inst. group includes Mr. and Mrs. W. R. Cuthbert. The boys are wearing hats in their school colors. They are Tom Denny, Lance Steahly, Jack Burks, Bob Smith, Warwick Doll, John Fuller, Tom Rose, Joey Simon, Richard Six, Melvin McGrew, Richard Folden, and Joe Strickland.

POSITION OPEN

AIME Western Field Secretary

LOCATION:	Salt Lake City
DUTIES:	Represent AIME National organization in Western States. Work with Local Sections. Report to AIME Secretary. Job entails considerable travel.
SALARY:	Depends on man, his qualifications and experience.
INTERESTED?	Send full resume to J. W. Woomer, J. W. Woomer & Associates, 821 Oliver Building, Pittsburgh 22, Pa. He is Chairman of committee charged with finding the right man for this job.

Coal News

(Continued from page 1163)

use of engineering instruments filled the first day, with swimming at Cheat Lake and dinner at Mont Chateau as guest of the School of Mines to round out the program. The second day contained seminars and work shop concerning mineral dressing and coal preparation, mine layout and production methods. That day they also discussed engineering and science education.

The third day the students visited the Greer limestone plant at Greer, W. Va. and the Federal No. 1 mine of Eastern Gas & Fuel Assocs. in Grant Town. A trip to Cadiz, Ohio, to see the Hanna Coal Co. surface mining operations was followed by a discussion of the mining methods demonstrated, and on the final day the students visited the Christopher Coal Co. properties for examination of underground and surface methods, highlighted by dinner at Mont Chateau as guests of the company.

In August, E. A. Dines was in charge of a group that visited the University of Pittsburgh. He was assisted by Holbrook G. Botset and J. Alfred Berger, professors. The group visited the Gulf Research Laboratory and were dinner guests of Eastern Gas & Fuel Assocs., with a National League baseball game as the climax of the day.

Harwick mines of Duquesne Light Co. welcomed the boys the next day and swimming at Dravo Corp. followed the tour of underground operations. The boys also toured the Weirton Steel Div. of National Steel Corp.; the Harbison-Walker Refractories Co. clay stripping operations; Garber Research Center; and the engineering departments of the university. Luncheons, a banquet, lectures and discussions filled every spare moment of the active schedule.

Perhaps the best proof of the value of these programs is the reaction of the boys themselves. Joe Benedict declares, for example, that "if more students took trips such as this one, there would never be a shortage of mining engineers. . . It is easy to tell what an engineer does, but a program such as this shows and demonstrates these things. It is the initial interest that is difficult to instill in a young potential engineer and seeing is worth a thousand words."

Paul W. Hoff described how he discovered that seismology, geophysics and mining processes were challenging and intriguing and said that "I thank you not only for the wonderful trip, but perhaps for deciding my career." Others also mentioned that they were seriously considering mining as a career and all expressed surprise at the magnitude and variety of opportunities within the field. If even a few of these students pursue their new-found interest in mining, the venture will be well worth the effort and support of the coal industry for insuring the supply of engineers for tomorrow.

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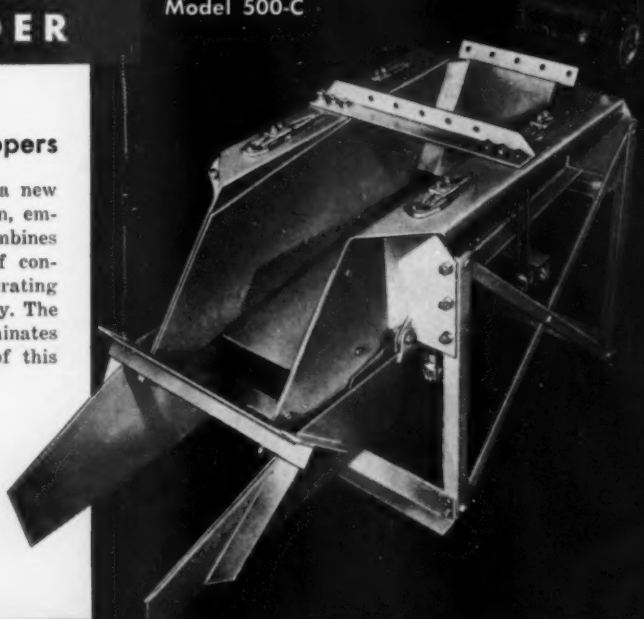

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MBD Annual Meeting Symposium To Cover Surface Phenomena

In February 1960 for the Annual Meeting the Basic Science Committee of MBD is planning a symposium on *Surface Phenomena in Mineral, Ceramic, and Metallurgical Systems*. This will be a joint symposium for the Society of Mining Engineers, Minerals Beneficiation Division, and The Metallurgical Society, Institute of Metals Division. There will be two sessions which will run as follows:

Morning—Elementary Concepts of Surface Energy and Their Applications in the Metallurgical Industry, by *C. S. Smith*. The Influence of Solutes on Interfacial Tensions and on the Contact Angle: Principles of Flotation, by *J. T. G. Overbeek*. Kinetics of Wetting and Surface Energies of Solid Metals, by *C. M. Adams*. And, Some Aspects of the Foaming of Fused Silicates, by *C. F. Cooper and C. L. McCabe*.

Afternoon—Crystal Growth in Solids, by *D. Turnbull*. Surface Chemistry and the Kinetics of Sintering Processes, by *W. D. Kingery*. Geometric Equilibria and Nonmetallic Microstructures, by *L. H. Van Vlack*. Graphite Formation and Surface Tension in Cast Iron, by *J. Keverian*.

This type of symposium will be quite novel to AIME members because it will attempt to cut across the Mining and Metallurgical Societies of the parent organization as well as across many other semi-rigid boundaries within each society.

The Basic Science Committee itself is of very recent origin. It was organized two years ago and given the opportunity to stress and defend the importance of basic research and a sound knowledge of scientific principles in the field of mineral engineering. Appropriately enough, the first chairman of this committee was Professor A. M. Gaudin, recipient of the Richards Award and today a recognized leader in basic research and teaching of mineral engineering.

During the first year of its existence, the committee attempted to define its role and scope. At this time, it was suggested that a symposium on a topic of live interest to many AIME members, for example on *Surface Phenomena*, be organized. This suggestion has now become a reality.

New Goals

The aims of this symposium are manifold. It is intended to determine if it is possible for such a big organization as the AIME to get its membership-at-large interested in one central theme. This aim is already partially achieved because the committee has had no trouble in obtaining speakers for this symposium even though these speakers have different associations within the AIME. In addition, the committee experienced no trouble soliciting the assistance and interest of other committees. The Physical Chemistry of Extractive Metallurgy and the Chemistry and Physics of Metals Committees, both committees within The Metallurgical Society, have given strong moral support and indicated their willingness to join in this effort. The final success of the symposium, of course, will depend on the interest shown by individual members of the AIME.

The second purpose of this symposium is to bring about cross-fertilization of ideas. The program as outlined has purposely not been designed only for MBD membership. This follows from a first glance at the symposium schedule. However, the research and practicing mineral engineers can gain something valuable from every one of the papers to be presented.

For example, the problem of wetting of solid metals so important to welding engineers, is basically no different from the problem of creating a water-repellent mineral surface in the flotation cell. The adsorption of sulfur at the graphite-melt interface in the preparation of cast iron must be related to the adsorption of xanthate at the galena-water interface. Froth formation in slags may be correlated with flotation froths. An understanding of the process of crystal growth in solids may help us to appreciate the importance of the role of solid surfaces in flotation; the sintering process depends on surface energy, so does the flotation process. Ceramic materials are solids; so are minerals, and flotation is an example of a *solid-solid separation* process.

The symposium has been designed primarily to create interest in basic research problems and to point out that concerning ourselves with these problems, which at times are seemingly far removed from the practical problem, will guarantee the future development of engineering.

P. L. DeBRUYN

Mr. de Bruyn is chairman of the Basic Science Committee, in addition to his position as associate professor of mineral engineering at Massachusetts Inst. of Technology. He received his doctorate in metallurgy from M.I.T. in 1952. His early education was in the Union of South Africa, where he was born.

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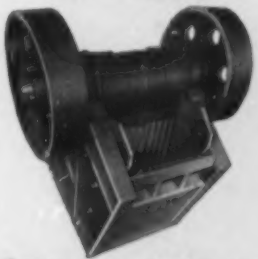

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"ONE OF THE MOST IMPORTANT QUALIFICATIONS for Jeffrey sales engineers," says W. G. Montgomery, District Manager at Bluefield, West Virginia, "is a keen power of observation. Thus he builds up experience that is invaluable to his customers." Montgomery is shown at Omar Mining Company, Omar, West Virginia, where Jeffrey recently system-engineered all cutting and loading equipment for Mine 15. The first new unit in service (cutter, loader and 2 shuttle cars per unit) has delivered 677 tons of clean coal per shift. Drift mine height is 39" to 56".

Jeffrey Service starts with system engineering

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JEFFREY TEAM ON THE JOB—System engineering gets follow through from an experienced team as new equipment goes into service. Shown are Montgomery; Sales Engineer P. M. Campbell; Application Engineer D. R. Ellis; Serviceman W. C. Mayo; Chief Demonstrator R. W. Ramer; Demonstrator L. Damron.

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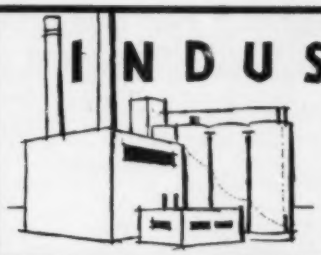


INDUSTRIAL MINERALS NEWSLETTER

Annual Meeting Papers Are Being Scheduled

The commodity committees of the Industrial Minerals Division have scheduled a number of outstanding papers for the AIME Annual Meeting to be held in New York next February. The committees and their hard-working chairmen are to be commended. While the program is not yet completed, here is a sample of what is being planned.

Dimension Stone and Slate Committee—Chairman Howard L. Hartman announces that four papers have lined up so far. A. Allan Bates plans to discuss *Trends in Construction and Architecture*. W. F. Mullen will give a paper entitled *Economic Health of the Dimension Stone Industry*. F. D. Hoyt and H. L. Hartman are preparing a talk on *Research in Sawing and Cutting of Dimension Stone;* and H. W. Straley III will consider *New Lightweight Aggregate*.

Chemical Raw Materials Committee—F. C. Kruger is chairman of this committee and reports that five papers have been selected. J. G. Cazort, Jr. will give the first presentation on *Development of a Bauxite Deposit Using Dredging as the Stripping Method*. Owen Kingman will describe *Zoning and Grade Control in Producing Sulfuric Acid at the Tennessee Copper Company, Copperhill, Tennessee*. Robert E. Hershey will talk about *The Phosphate Raw Materials of Tennessee* and John M. Warde will give the paper *Refractory Chrome Ore—World Survey*. The final paper of the session will be *Fracturing Technique in Wet Salt Mining*, by C. H. Jacoby.

Industrial Waters Committee—William F. Guyton is the chairman who has lined up five papers, beginning with *Water: Industrial Mineral— and Industrial Nuisance*, by Raphael G. Kazmann. Next is *The Cost of Converted Water* by W. Sherman Gillam. *Development of Extreme Settings on Deep Well Turbine Pumps* will be the third paper, presented by Claude E. Wykes. Stanley Michaelson will discuss *Use of Water in Mining Operations* and Douglas Ball will wind up the session with *Underground Storage of Natural Gas and its Relation to Ground Water, Including Brines*.

Fillers and Fibers Committee—The chairman, Robert S. McClellan, has scheduled the following papers: *A Study of the Abrasive Action of Fine Powders* by L. E. Weymouth, F. L. Kadey, Jr., and F. B. Hutto, Jr; *Relationship of Hardness, Friability and Particle Size on Abrasive Action* by H. L. King; *Beneficiation Methods used in the Processing of Fillers, Fibers, and Pigments* by Donald R. Irving; *Fillers in Plastics* by Robert D. Thomson; and *Opening Up New Marketing Areas* by Bror Nordberg.

Rare and Radioactive Materials Committee—Chairman Ralph H. Wilpolt starts his session with *Non-Pegmatitic Deposits of Beryllium in the United States by* W. R. Griffiths. Then Margaret Fuller Boos will present the topic *Pegmatites and Their Mineralization in the Storm Mountain Area, Larimer County, Colorado*. Judson H. Whitman will discuss *Evaluation and Marketing of Rare Earth Deposits, Ores and Concentrates*, and Robert M. Grogan will wind up the session with a talk on *Niobium at Powderhorn, Colorado*.

Cement, Lime and Gypsum Committee—Ross W. Smith, chairman, so far has three papers in the works for his session. James D. Piper plans to present the first entitled *Concrete Technology in the U.S.S.R.* Warren H. Weisz will give the second on *The Role of Gypsum in Portland Cement;* and O. E. Brown will discuss *Use of the Coulter Counter for Particle Size Analysis of Cement*.

There are also papers planned by the Ceramic Raw Materials Committee with Wayne E. Brownell as chairman; the Mineral Aggregates Committee, James V. Thompson, chairman; and the Special Sands and Abrasives Committee, Herbert E. Dux, chairman. Further reports on progress of these committees, changes in program, and additions to the list of papers will be featured in later issues. Contact Leon W. Dupuy, program chairman for the Division, for the latest data on Annual Meeting plans.

EDITOR

Address news items to:

R. H. Feierabend, IndMD Secretary-Treasurer, Freeport Sulphur Co., P. O. Box 1520, New Orleans 5, La.

Board of Directors

(Continued from page 1162)

Council of ECPD for a 3-year term from October 1959 to October 1962.

► John J. Reed has been appointed principal Aime representative on the Ethics Committee to succeed Clyde Williams who had resigned. J. E. Monroe was appointed as alternate.

► J. E. Warren has been appointed as alternate to C. E. Reistle, Jr., on the John Fritz Medal Board of Award.

► R. L. Whiting has been appointed chairman of the Campaign to Develop Interest in Earth Sciences & Mineral Industries. R. Schuhmann, Jr., had declined the appointment as chairman although willing to serve as a member.

► AIME is a member organization of The American Geological Institute. The AIME board has again signified its continuing support of AGI by voting a token contribution.

► Joseph L. Gillson has been appointed official delegate to the 1960 International Geological Congress in Copenhagen.

► *Revised Rules.* Since no provision has been made in the Rules for approving salary changes for employes receiving less than $9000 per year, the following Rule was recommended:

Article V, Section 10, Rule 1 b)—The Salary Committee shall review all requests of the Institute Secretary for salary changes and effective dates thereof of all non-Society employees receiving less than $9000 per year. If approved, the salary changes become effective on the date recommended. If not approved, either with regard to salary or effective date, the Secretary may then bring the recommendation to the AIME board of directors for final action at its next meeting. Salarics of Society employees receiving less than $9000 per year shall be established or changed by the respective Society Boards of Directors or their Salary Committees.

► Revised bylaws of the Extractive Metallurgy Division were approved.

► Revised bylaws of the San Francisco Section have been approved.

WAAIME Sponsors Challenging Tours To Attract Engineers For Tomorrow

Engineers for Tomorrow is the title and theme of the program aimed at interesting the science-minded high school students of today in the future of engineering. The Woman's Auxiliary of AIME, Western Pennsylvania Section, last year initiated the Pilot Student Venture to send 10 boys to the University of West Virginia for an insight into campus life and engineering classes, plus a look at mining properties to see engineering in action. Response to this program was so enthusiastic that this year four universities and 48 boys participated in the expanded venture.

The boys had been selected by examination from a list of 129 outstanding students submitted by principals of 43 high schools. Eighteen WAAIME members contacted the high schools, nine conducted interviews in the Western Pennsylvania area and Mr. and Mrs. W. Cuthbert interviewed students in Charleston. Mrs. Harry F. Lawrence, chairman, and Mrs. Stephen Krickovic, co-chairman, arranged the programs with the universities. WAAIME financed the board and lodging at the universities plus transportation and meals that were not otherwise provided by industry.

The four universities visited were Pennsylvania State University, Virginia Polytechnic Inst., West Virginia University, and the University of Pittsburgh. For the Penn State and West Virginia University trips two high school science teachers volunteered to act as counselors. They themselves gained new insight into the mineral industries and were as impressed as the students, which will undoubtedly be reflected in their classroom teaching.

The National Woman's Auxiliary of AIME created the Secondary School Student Counseling and Guidance Committee in 1958 to find a workable way of stimulating interest in careers in mining, metallurgical, and petroleum engineering among high school students. Inspired by the success of their first trial venture, the 15 committee members from various sections of the country have announced the eagerness of other sections to sponsor similar programs.

Mrs. S. D. Michaelson, representative from the Salt Lake City Section, reported that the section has been working with a teacher specially trained in earth sciences who selected 35 ninth grade students to attend a special workshop. Scrap books, maps, pictures, articles, and rock collections helped the students gather engineering knowledge. The Utah Copper Co. prepared a field trip through all their operations from open pit mining to the finished copper. The students received a certificate of award for their participation in the special course. The Salt Lake City Section was very pleased with the program results and hopes to convince local school boards to make this type of program a permanent part of the school.

The Alabama Section, represented by Mrs. R. S. White, participated in the Secondary School Student Counseling and Guidance program with a barbecue in August. Six seniors from Bessemer, Ensley, Fairfield, and Jones Valley High Schools were entertained by Mr. and Mrs. P. J. Zukow, Mr. and Mrs. R. S. White, and Mr. Nat Ginn with short talks and an exhibit of minerals from various parts of the U. S. A round table discussion followed to answer questions concerning mining engineering, curricula, and student life.

The Rolla Missouri Section cooperated with the National Science Foundation in arranging a dinner for 34 high school seniors who had been sent to the Missouri School of Mines and Metallurgy for a six-week period. Lectures by industrialists, laboratory sessions, and field trips were included in the NSF program. Mrs. R. Hanley is the WAAIME representative.

Mrs. F. R. Morall, representative for the Columbus Section, reports that the section is very enthusiastic about the program and to date has contacted the schools, the university, and Battelle Memorial Inst., hoping to have a report by January.

The reactions of the university and industry personnel, and of the boys themselves have completely convinced the auxiliary that their program is accomplishing its purpose. Howard L. Hartman, head of the Dept. of Mining, Pennsylvania State University declared that "the program has merit and certainly warrants the country-wide participation and support of the AIME. I hope that it becomes an annual event in the future."

G. Ralph Spindler, dean of the School of Mines, West Virginia University, gave his unqualified support to the program. "From our viewpoint we were exceedingly well pleased with the visit. You certainly sent us a fine group of boys and we were extremely glad to have had them. It is also hoped that some of them will be attracted to the mineral industries for their educational specialization and future employment as they represent some excellent prospects for whatever field they may select."

Enthusiastic comments were also received from industry executives. Typical comment comes from the president of a coal company who was "greatly impressed by the interest, enthusiasm, and intelligence of the boys who visited our operations. My only regret is that your program could not have handled all 129 of the boys." With the further support of WAAIME sections, the high schools, universities, and industry, perhaps this wish will be fulfilled next year and the year after, with ever expanding interest in the future of our young engineers.

The completed tours are not the end of the Western Pennsylvania Section's activities on this project. Follow-up literature and lists of accredited schools and recommended reading will be sent to the participating students to maintain their interest.

WAAIME Sections join the swim to win enthusiasm for mining as a career. At left, students sponsored by the Alabama Section display their rock collection. Pictured from left are Mrs. P. J. Zukow, WAAIME representative, Nat Ginn, Charles Grabin, Walter McAlister, Kenneth Williams, Jerry Bell, Larry Williams, Mrs. R. S. White, and Sanford Enslen. At the right are the Salt Lake City students and guides during their visit to the Utah Copper Co. For more information on the student tours, see Coal News, page 1163.

Southeast Section Met In The Smoky Mountains

The Southeast Section meeting was held at Riverside Hotel in Gatlinburg, Tenn., September 25 and 26, with over 100 engineers registering for the conference. Special guests President Howard C. Pyle and Secretary Ernest Kirkendall honored the meeting. A well balanced program of technical papers and social events, including a colorful fall football game, made a worthwhile weekend in the Smoky Mountains.

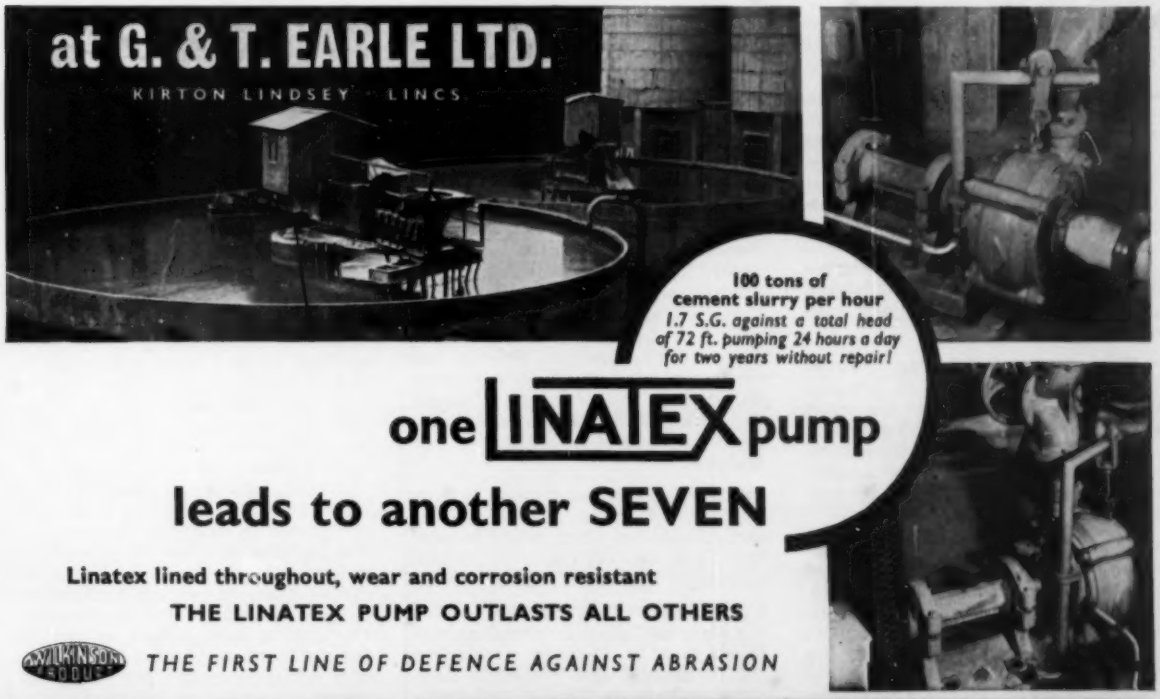
Sessions began on Friday morning in Stevens Hall with two papers presented before lunch. E. G. Struxness gave the first on the topic of *Ground Disposal of Radioactive Wastes*. Mr. Struxness is assistant director of the Health-Physics Division, Oak Ridge National Laboratory. *Mechanized Mining at American Zinc Co.* was the second paper, presented by Harry L. Miller, superintendent, Jefferson County Operations, American Zinc Co.

The afternoon session contained three papers. *Ventilation of Ore Mines of Tennessee Coal and Iron Div., U. S. Steel Corp.* was presented by M. N. Zukow. *Crystal Defects and the Properties of Crystals* was given by E. E. Stansbury, professor of metallurgical engineering, University of Tennessee. And Paul I. Eimon, assistant exploration supervisor, Eastern U. S. Division, American Smelting and Refining Co., discussed *Applications of Photogrammetry in the Mining Industry*.

A social hour, banquet, and dance completed the day. M. J. Langley, chairman of the Southeast Section, presided at the banquet. He introduced AIME President Howard C. Pyle, who commented on Institute activities. The major address of the evening was given by Hugh T. McDade, public relations manager, Tennessee operations, Aluminum Co. of America. From 9 o'clock on music by The Martiniques enticed the members and wives to dance.

Saturday morning, bright and early, the field trip began. Cars assembled in front of the hotel for the trip to Gray Knox Marble Quarry and Manufacturing Plant in Knoxville, Tenn. Then brunch was at the Holston Hills Country Club, followed by the football game with Auburn vs University of Tennessee. Those who didn't attend the game played golf at the Gatlinburg Country Club, or enjoyed the scenic spots of interest in the surrounding Smokies. Saturday night was filled with entertainment at the Mountain Frolic, the final event, with Sunday free for driving home.

At the head table are Mrs. McDade; Mr. and Mrs. M. J. Langley; Hugh McDade; Howard C. Pyle and Mrs. Pyle; and Ernest Kirkendall.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Around the Sections

• October 7 was the date of the first meeting of the new season for the **Chicago Section.** Maxim M. Cohen, general manager of Chicago Regional Port Authority, covered the topic of the commercial and industrial background of the port's development.

• A fall field trip for the **Lehigh Valley Section** toured the Friendensville mine of New Jersey Zinc Co. near Bethlehem, Pa., on September 19.

• An illustrated talk by Richard Hamburger of the Division of Military Application, U. S. Atomic Energy Commission, covered various aspects of the Plowshare Program at the dinner meeting **Washington, D. C. Section,** October 6.

• Enrique Madero, secretary-treasurer of the **Mexico Section,** opened the meeting on September 14 and introduced Richard V. Gaines who discussed *New Treatment Methods for Scheelite Concentrates.*

• The **Southwestern New Mexico Section** held its annual picnic at the Cameron Creek Picnic Grounds on July 31 with 90 members enjoying the ideal weather and food.

• **The Carolina Subsection** of the Southeast Section held a dinner meeting on September 4 at the Mayview Manor in Blowing Rock, N. C. Guest speaker was P. Eckman, mine manager of Appalachian Sulphides Inc. Mr. Eckman presented a review of the history and current operations of the Ore Knob mine near Jefferson, N. C. The following day a tour of the mine and mill completed the schedule.

• The **MBD Subsection,** Upper Peninsula Section, met at Ishpeming, Mich. on August 12 for their summer meeting. Robert Yardley of Industrial Nucleonics Corp. demonstrated operating models of nuclear instruments for process control. Cocktails and dinner followed.

• On September 19 the **Upper Peninsula Section** fall meeting was held in White Pine, Mich. Trips through the mine and power plant, concentrator, and smelter filled the morning. A buffet luncheon preceded the business meeting and cocktails and dinner followed at the Ontonagon Country Club. Present officers of the Section include J. C. Wangaard, chairman, Kiril Spiroff, vice chairman, and Roy Drier, secretary-treasurer.

• The **Colorado Section** began its fall series of meetings on September 17 at the Petroleum Club in Denver. The dinner meeting featured a discussion of explosion research in blasting of mines and quarries by Clifton W. Livingston.

• The **El Paso Section** welcomed W. E. Cline for a film and talk on productive maintenance at the Hotel Cortez on September 9. Mr. Cline works for General Electric Co.

• An interesting talk and pictures were presented by A. H. Kinneberg at the **Morenci Subsection,** Arizona Section, meeting on September 8. Mr. Kinneberg discussed his experiences at the Braden operation in Chile.

• On August 19 at the Hotel Bolivar the **Lima, Peru Section** featured a talk by Alfonso Ballón, consultor, Cia. Explotadora de Hierro de Acari, entitled *Proyecto de Hierro-Acari.*

• The **Arizona Section** is steaming ahead in its drive for the United Engineering Center Fund. Committees have been organized to cover every area. The chairmen of these committees are as follows: C. R. Kuzell, Pheonix; A. T. Barr, Southern Arizona; J. D. Forrester, Tucson -San Manuel-Benson area; D. Gardner, Superior; F. G. Woodruff, Hayden-Winkleman-Kearny area; J. A. Lentz, Morenci-Duncan Safford area; G. W. Colville, Bagdad-Prescott; B. R. Coil, Miami-Globe area; H. C. Weed, Inspiration-Christmas-Claypool area; and J. C. Van De Water in the Ray area.

John A. Lentz, manager of Phelps Dodge Corp., Morenci Branch, has been appointed to the board of directors of the Arizona Chapter, American Mining Congress, to complete the term of L. M. Barker who resigned.

• The **San Francisco Section** met on September 9 at the Engineers Club and heard Ian Campbell, chief of the California Division of Mines, discuss the prospects for the 1960's.

• The **Adirondack Section** visited the plant of Canadian Titanium Pigments Ltd. in Montreal to observe the processing and materials handling techniques. Dinner and dancing filled the evening.

On September 26 a tour of the Hyde Park, Vermont, operations of the Ruberoid Co. was held, with dinner at Skimore Lodge in Stowe, Vt.

Alaska Section Hears Warning On Minerals

The Southwest Alaska Section was host to Sherwin F. Kelly as guest speaker at the Section meeting, August 6. Members of the Alaska Section were also present to welcome Mr. Kelly who was acting as official representative of AIME President Howard C. Pyle.

Mr. Kelly is president of two geophysical companies, Sherwin F. Kelly Geophysical Services Inc. in New York and Geophysical Explorations Ltd. in Toronto. He was a pioneer in geophysical techniques in the U. S. and Canada in 1921 for the Schlumberger Co. of France.

A warning was the keynote of his talk as he declared that the world supply of minerals could be depleted in five years if world-wide consumption reached the level of U.S. demand for metals and metallic products.

In a comparison of mineral exploration and the science of manufacturing, Mr. Kelly said that prospecting and exploration are still in the hand craft stage. Methods of searching for metallic minerals must be improved to match the tools of the petroleum industry. This will take the best knowledge in the fields of geophysics, geochemistry, and geology, working in world-wide cooperation.

He suggested first that a study of the earth's crust in relation to formation of mineral deposits is vitally important. After the entire earth is studied, then a narrowing inspection of continents, geological locales, and individual faults will be necessary in the massive program. This thorough search will demand all the tools science now has available.

And in addition to scientific tools already in their advanced stage, improvement in scientific instruments and methods will have to be made in order to permit boring deep into the earth's crust. At present, minerals no deeper than 300 ft can be detected. For only a core sample sought by the drill bit can give the true nature of a mineral deposit, Mr. Kelly asserted.

Mr. Kelly was on his first visit to Alaska, though he had worked often in British Columbia.

Personals

In the October issue, page 1058, **George F. Halfacre's** new position was incorrectly described. He is actually vice president in charge of manufacturing at The New Jersey Zinc Co.

Cooper H. Wayman was awarded a Ph.D. in geochemistry from Michigan state University in September. He was an instructor in the geology department, but now has become senior technologist at Research Center, U. S. Steel Corp., in Monroeville, Pa.

Kenneth M. Judd is an associate in the law firm of Koener, Young, McCulloch, and Dezendorf in Portland.

Clayton E. Warren, formerly production engineer for Spanish American Mine, now is assistant mine superintendent for Canadian Dyno Mines in Bancroft, Ont.

Norman H. Parker, who was manager of engineering for Turbo-Mixer Div., General American Transportation, has accepted the position of manager, industrial division, for Tower Iron Works Inc. His article *Buying Process Equipment* is soon to be published.

John W. F. Dulles has moved from Mexico to Belo Horizonte, Brazil, to work for Mineracao Hannaco Ltda.

R. T. Hair, who had recently been appointed general sales manager, Coal Machinery Div., for Joy Manufacturing Co. now has been named vice president, technical services, for the division.

The board of governors of the Western Division, American Mining Congress, elected **J. C. Kinnear, Jr.,** general manager of the Nevada Mines Div., Kennecott Copper Corp., to serve as chairman, succeeding **Cris Dobbins** who is president of Ideal Cement. Other members of the board include: **Lockwood W. Ferris,** president and general manager of Bonneville Ltd.; **Oscar A. Glaeser,** vice president and general manager of Western Operations, United States Smelting, Refining and Mining Co.; **Miles P. Romney,** manager, Utah Mining Assn.; **Wallace G. Woolf,** vice president of Bunker Hill Co.; **J. C. Kieffer,** general manager of American Smelting and Refining Co.; and **A. J. Taske,** secretary of the Idaho Mining Assn.

C. A. ANDERSON

M. H. SHUMATE

Charles A. Anderson has been advanced to administrative geologist and chief of the Geologic Division for the U. S. Geological Survey. He succeeds **Wilmot H. Bradley** who recently retired.

Mack H. Shumate tranferred to the general offices in Chicago of the Truax-Traer Coal Co. from the West Virginia mining properties. Formerly he was assistant general manager and now he is chief engineer.

Clark L. Wilson, vice president of the New Park Mining Co., has been elected chairman of the Western Governors Minerals Advisory Council, succeeding **S. H. Williston,** vice president of Cordero Mining Co. Vice chairman is **W. G. Maloney,** consultant for the Mining Assn. of Montana. **Frank P. Knight** of the

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Former Title ..... Length of Time There .....

New Company .....

New Title ..... Date of Change .....

.....

Any recent activity that would be of interest to members:

.....

.....

personals

continued

Arizona Dept. of Resources became secretary.

Robert H. Raring has been named business development engineer for Western-Knapp Engineering Co. of San Francisco. He has been involved in gold mining operations in Nevada, British Columbia, and Equador.

David L. Francis, president of Princess Coals Inc., has been reappointed chairman of the Natural Resources Committee, U. S. Chamber of Commerce. Other members of the committee advising the board of issues affecting coal are as follows: **F. S. Elfred**, Peabody Coal Co.; **Norman E. Kelb,** Ayrshire Collieries Corp.; **Erwin R. Phelps,** Pittsburg & Midway Coal Mining Co.; **Rodney E. Sachs,** Boone County Coal Corp.; and **Walter F. Schulten,** Consolidation Coal Co. Inc. Advisory members for minerals and metals are: **Floyd B. Bowen,** International Minerals & Chemical Corp.; **Morris A. Bradley,** M. A. Hanna Co.; **Chad F. Calhoun,** Kaiser Aluminum & Chemical Corp.; **John C. Carrington,** Freeport Sulphur Co.; **Fred P. Curtis,** Lyman-Richey Sand & Gravel Corp.; **Oscar A. Glaeser,** U. S. Smelting, Refining and Mining Co.; **Paul B. Jessup,** Kennecott Copper Corp.; **Kenneth C. Kellar,** Homestake Mining Co.; **Charles E. Schwab,** The Bunker Hill Co.; and **Felix E. Wormser,** St. Joseph Lead Co.

Walter R. Shaw has been named project engineer for Western-Knapp Engineering Co., responsible for design, layout, and process engineering on chemical and ore processing plants. Formerly he was manager of a seawater magnesia and basic refractory material plant of the H. K. Porter Co. Inc.

John C. Russell has been appointed manager of metallurgical engineering for Singmaster & Breyer Inc. Previously he had been project engineer for the firm on a plutonium laboratory building for the Argonne National Laboratory.

Joy Manufacturing Co. presented awards to employes who had served the company for many years. **B. P. Lane,** manager of export sales, and **C. Darrell Smith,** manager of distributor sales, received thirty-five year awards. **W. J. Whinnen,** manager of diamond bits and core drills accessory sales, was rewarded for twenty years of service.

Roy B. Young has been appointed assistant general manager of Ray Mines Div., Kennecott Copper Corp., to succeed **H. J. O'Carroll** who has retired. Mr. Young was the general manager of Quebec Iron & Titanium Corp., Kennecott subsidiary.

Clinton C. Knox has transferred from Joplin, Mo., to Bartlesville, Okla., as mining engineer, Div. of Mineral Resources, Region IV, U. S. Bureau of Mines. He had been the executive officer of the regional field team and chairman of the Tri-State Section. A decrease in exploration activities has made the move advisable.

Lloyd E. Antonides is now mining engineer for Associated Metals & Minerals Corp. He had been associate editor of *Engineering and Mining Journal* for the past four years.

R. M. McAlexander, formerly geologist for State Land Office, now is shift boss, geologist-engineer for Gunnison Mining Co.

Ciro T. Mundaca of Staten Island, N.Y., formerly structural designer for Anaconda-Jurden Assocs., has become layout designer and plant design engineer for M. W. Kellogg Co.

J. E. CARR

S. MUESSIG

J. E. Carr, who has been with the sales staff of Denver Equipment Co. for the past three years, has been appointed manager of the new chemical processing and sewage treatment equipment division.

Siegfried Muessig has been appointed chief geologist for United States Borax & Chemical Corp. He has spent eight years with the mineral deposits branch of the U. S. Geological Survey.

W. Edwin Dill, Jr., has moved from Virginia to Philadelphia as mining engineer for E. J. Lavino Co. He had been employed by Foote Mineral Co.

Ronald Sager has completed U. S. Army service and is mining engineer for Bestwell Gypsum Co. in Grand Rapids, Mich.

Gerald L. Schierman has become a mill engineer for New Jersey Zinc Co. in Hanover, N. M.

Charles K. McArthur, formerly technical director of National Lead Co. Inc. in Winchester, Mass., now is director of metallurgical research for Utah Construction and Mining Co. in Palo Alto, Calif.

James C. Ferrell has been named sales engineer for Tidewater Supply Co. after leaving the Soil Conservation Service where he was geologist. He has moved from Salisbury to Greensboro, N. C.

Roderick G. Murchison has spent 2½ years in Africa as resident geologist for Kennecott Copper Corp. and now is a minerals technologist for the U. S. Bureau of Mines. He was temporarily in Washington, D. C., taking ICA orientation preparatory to going to Vientiane, Laos, in October as mining advisor to the Laos Government.

Gordon E. Frantti, formerly geophysicist for the U.S. Bureau of Mines in Minneapolis, now is assistant professor in the Physics Dept. at Michigan College of Mining and Technology.

F. Newton Parks has been transferred to the European operation of Booz, Allen & Hamilton International Ltd., management consultants, and is located in Zurich, Switzerland.

James A. Drain, formerly vice president and general manager of Mining and Construction Div., Joy Manufacturing Co., has left that firm to become vice president of the H. K. Porter Co. Inc. in Pittsburgh.

Harry M. Tibbs has been transferred to the Chicago office of Truax-Traer Coal Co.

G. W. Sheary III has changed his position from the Raw Materials Research Div. of Bethlehem Steel Co. in Lebanon, Pa. to metallurgical engineer for Bethlehem Cornwall Corp. in Morgantown, Pa.

C. E. Reistle, Jr., AIME Past-President, is slated to become executive vice president of the new Humble Oil & Refining Co. under which Standard Oil (N. J.) Co. plans to consolidate most of its domestic operations. Other top officers of the company, which will have its headquarters in Houston, are **Morgan J. Davis,** president; and **John W. Brice** and **William Naden,** executive vice presidents.

David Williams has been elected president of the Institution of Mining and Metallurgy for 1960-1961. Dr. Williams occupies the University of London Chair of Mining Geology at the Imperial College of Science and Technology.

Attilio Ligasacchi spent a year as field geologist in Italy and has been studying for a masters degree in geology at the Missouri School of Mining and Metallurgy since 1957. Now he is assistant smelter metallurgist for Kennecott Copper Corp. in New Mexico.

Roblee B. Martin, formerly director of research development for Mississippi Lime Co., has become general manager of Dundee Cement Co.

James W. Cole transferred to Brazil to work on pyrochlore deposits at Aquas Do Araxa, Minas Gerais, as

a research engineer for Wah Chang Corp.

M. P. ROMNEY

H. S. FOWLER

Hedley S. Fowler has transferred from Kaiser Aluminum & Chemical Corp. to Kaiser Engineers & Constructers Inc. His present work is engineer-in-charge of site investigation for the dam of the Volta River Hydro-electric and Aluminum Development Scheme in Ghana, Africa.

Miles P. Romney, manager of the Utah Mining Assn., has been named chairman of the Emergency Lead-Zinc Committee. He succeeds **Charles E. Schwab,** who has been named general manager of Kellogg, Idaho operations of Bunker Hill Co.

James E. Adler graduated from the University of Oregon and became assistant surveyor for American Chrome Co., in Nye, Mont.

O. A. Sundness has retired from his position of vice president, general manager of Snyder Mining Co. and has become a consultant. He is studying the iron ore possibilities in Arizona and northern Mexico.

Werner Joseph has been transferred within the company to the position of assistant chief metallurgist for Mauricio Hochschild & Cia. Ltda., working now in Lima, Peru instead of Antofagasta, Chile.

Tom Rosadiuk has become an engineer for Cripple Creek Coal Co. Alaska.

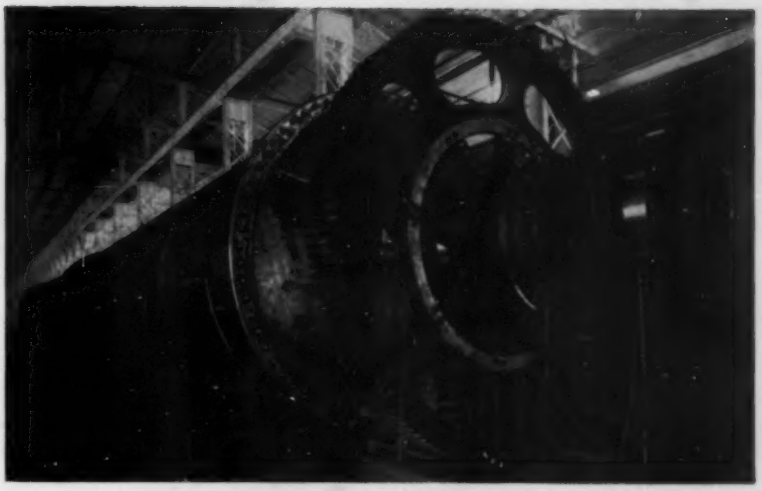
H. S. Tomlinson has left Eldorado Mining and Refining Co. in Saskatchewan and has returned to the Royal School of Mines in London for a research project.

David W. Stevens, formerly mining engineer for Imperial Colliery Co., received an M.S. from Virginia Polytechnic Institute and now is engineer trainee with Bethlehem Mines Corp. in Jenkins, Ky.

W. F. Keyes of the U. S. Bureau of Mines completed his assignment as minerals advisor to the Cuban Government and is back in Washington awaiting reassignment.

Clyde W. Nicolson has retired from his position as manager of North Range Mining Co. in Negaunee, Mich., and is located in Rialto, Calif.

Howard H. Braden, formerly acting chief engineer for Calera Mining Co., has accepted the position of mining engineer with Western Nuclear Corp. in Wyoming.



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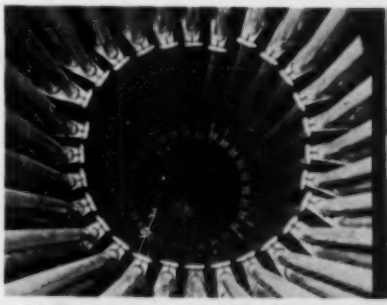
GAS-COOLED TYPE—Solids are cooled by direct contact with cooling air (atmospheric, or dried and refrigerated). Inert gases may be used in a closed system.

WATER-COOLED SHELL—Water is externally applied to the shell, either by sprays or by partially submerging the shell.

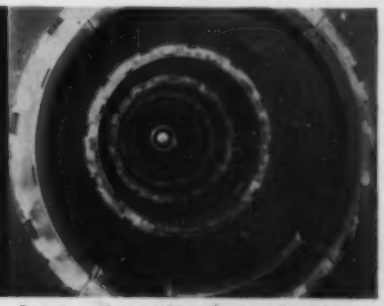
TUBULAR TYPE—Internal water-cooling tubes are assembled with the rotating shell, or installed as a stationary bank of tubes concentric with the shell. Alternately, the water leaving either of these tube sections may be used for supplemental spray cooling on the shell exterior.

DIRECT-CONTACT WATER—For rapid cooling from very high temperatures, water is sprayed directly on the hot material to utilize the latent heat of vaporization. Usually supplemented by secondary air cooling.

Each of these types has a particular area in which it is most economically applied. Write for further information.



Interior of a water-tube cooler. Longitudinal banks of tubes provide maximum cooling surface for minimum floor space.



Interior of partially-submerged cooler with gravity-controlled scrapers maintaining clean shell surface for high-rate heat transfer.

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continued

Kevin Fletcher has transferred from Atlanta to Pittsburgh with Sprague and Henwood Inc. in his capacity as assistant vice president.

Fred Pickwick, Jr., is a metallurgical engineer with the U. S. Atomic Energy Commission, after spending a year as metallurgist for The Anaconda Co.

Eugene S. Allen, formerly mill manager for Homestake Sapin Partners, now is senior project engineer for Utah Construction and Mining Co. in Los Altos, Calif.

Wilbur F. Criswell is trying to develop sources of raw materials, domestic and foreign, for Ray-O-Vac Co.'s battery manufacturing operations. He had been resident manager for Umont Mining Inc. in Butte, Mont. and now is in Madison, Wis.

Paul D. Chamberlin is an engineering trainee for Oliver Iron Mining Div. of U. S. Steel Corp. He had been a student at Michigan College of Mining and Technology.

Elliott F. Dressner, formerly geologist for International Minerals & Chemical Corp., now is chief ore engineer with Lone Star Steel Co. in Lone Star, Texas.

Evan Bennett is currently working on a coal mining project in Yugoslavia. He was vice president and director of World Mining Consultants, and now is consulting mining engineer with Resources Research Inc.

Donald H. Bailey, formerly research engineer for Ruberoid, now is mining engineer for Cerro De Pasco Corp. in Morococha, Peru.

Glen Sherman Wyman, shown here at left, who is general manager of Andes Copper Mining Co., has been awarded the Medal of Bernardo O'Higgins by the Republic of Chile. At right is Sr. Fernando Illanes, director, economics section, of Chile's State Dept.

John I. Schumacher has moved to Vancouver to acquire an interest in and manage Engineering Drillers Ltd. He was a managing partner of Strategic Minerals Exploration Co. for eight years. He is available for consulting work in western Canada.

James K. Richardson, assistant general manager of the Chino Mines Div. of Kennecott Copper Corp., has resigned to accept a position as vice president and general manager of Glover Associates (Canada) Ltd. in Montreal.

Houston N. Clark, assistant to the president of Potash Co. of America has been named general manager of Potash Co. of America Ltd., Canadian subsidiary.

Thomas I. Sharps, who was resident geologist for Calumet & Hecla Inc. in Michigan, now is technical representative for Keuffel & Esser Co. in New York.

Richard L. Rhodes, Jr. completed requirements for an M.S. degree at Syracuse University where he was graduate assistant, and now is geologist for Hope Natural Gas Co.

W. PETTIJOHN A. L. HAYES

Neill K. Banks has been elected president of Texas-Zinc Minerals Corp. to succeed **A. L. Hayes,** who returned to New Jersey Zinc to take over a new post as head of western mining operations. Headquarters for both will be in Grand Junction, Colo.

William T. Pettijohn has become manager of mines for The New Jersey Zinc Co., with headquarters in New York. **Johnson Crawford** will be assistant manager in Jefferson City, Tenn.

Alan Howe, formerly technical advisor for The Ham River Grit Co. Ltd., now is chief assistant for Victor S. Wicmore, consulting engineer in London.

Sam K. Smyth has moved from Tucson to Safford, Ariz., in a new position as engineer for Kennecott Copper Corp. He had been with Bear Creak Mining Co.

Neil L. Anderson left Rochester, Minn. where he was bridge engineer for the Minnesota Highway Dept. and is assistant area engineer for S. J. Groves & Sons Co. in the construction of an Air Force Base, in Burlington, Wis.

Kenneth H. Wright, who was consecutively mining engineer, assistant, metallurgist, and blasting foreman for Jones & Laughlin Steel

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Corp. in Star Lake, N. Y., now is mill engineer for New Jersey Zinc Co. in the Flat Gap Mine, Treadway, Tenn.

George A. Parks has completed work on an Sc.D. degree in mineral engineering at Massachusetts Inst. of Technology where he was an instructor in metallurgy and now is assistant professor of mineral engineering at Stanford University.

Peter A. Rutledge, formerly student at Colorado School of Mines, graduated in May with an E.M. degree and began as operations trainee for The Anaconda Co.

Donald W. Lindgren, formerly chief mining geologist of the Northern Pacific Railway, and **Ernest K. Lehmann,** consulting geologist, have formed the firm of Lindgren & Lehmann, consulting mining geologists, with offices in St. Paul and Minneapolis.

David M. Checkley, former manager of the Industrial Engineering Div. of Arthur G. McKee & Co., Cleveland, has been named president of Vitro Engineering Co. in New York.

Norman H. Parker has joined Tower Iron Works Inc. as manager of the Industrial Div. He was formerly manager of Engineering, Turbo-Mixer Div., General American Transportation Corp.

Silica Corp. announced that **Arthur Yarberry,** Colorado School of Mines graduate geologist engineer, and **Jack Hamilton,** Elkhorn City, would head operations of its new processing plant. **James E. Vance** and **George Norvell** will supervise sales. The vast silica sand deposit on Pine Mountain was discovered by Mr. Vance, Mr. Norvell, and **Joe Weddington.**

W. D. GOULD

J. A. MARTINO

Wayne D. Gould has been named to head the mining section of the Dow Chemical Co.'s technical service and development department. He has been with the firm since 1957.

Joseph A. Martino, president of National Lead Co., was the guest of honor at a dinner sponsored by the non-ferrous metals industry on October 15 at the Waldorf-Astoria. **C. R. Cox,** president of Kennecott Copper Corp., was campaign chairman. The dinner was for the benefit of the National Conference of Christians and Jews, which presented Mr. Martino with a Brotherhood Award.

Robert W. Lawson, branch manager

One of the many drill rigs now in operation throughout the United States and overseas.

The most important primary phase of construction, roadbuilding or mining begins with foundation investigation or exploratory work from which it is desired to get complete information and best possible cores. In many instances, contractors make the mistake of bidding on work or taking a contract without complete knowledge of sub-surface conditions, or miners will start mining operations without first conducting a thorough exploration program, but successful contractors and mining men always investigate first to know how to quote in order to get the contract and still make a profit, and how to plan to have a successful operation. One of the most reliable organizations in America for furnishing this information and satisfactory cores is Sprague & Henwood, Inc. For more than seventy years it has been rendering satisfactory core drilling service throughout the United States and the world. Many of its customers have continuing contracts with Sprague & Henwood, Inc., because they know that they can be assured of the best in foundation investigation and core drilling service that can be found anywhere.

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personals

continued

of Ingersoll-Rand Co., was named manager at Buffalo. **Robert L. Olund,** former branch manager at Butte, Mont., will manage the post at Salt Lake City, Mr. Larsen's former position.

Herbert E. Haymaker has been appointed manager of Fairchild Aerial Surveys' sales office in Denver. He has spent 14 years with the firm in office and field sales.

Brian P. Canning, who has been general foreman at the El Salvador concentrator of Andes Copper Mining Co., in August became mill superintendent for Northern Peru Mining Corp. in Shorey, Peru.

Petros G. Zambas, mining engineer for two years in Cyprus for the Hellenic Mining Co., has returned to the States as level boss for Kermac Nuclear Fuels Corp. in Grants, N. M.

H. Prud'Homme, who has been assistant director of the World Bank, Dept. of Operations, South Asia and Middle East, now is assistant to the chancellor of the University of Hartford in Connecticut.

Obituaries

Malcolm B. Kildale

An Appreciation By
Vincent D. Perry

Malcolm B. Kildale (Member 1940) died in Salt Lake City June 13, 1959, after an illness of approximately three months. To his many friends and associates who knew him as "Mike," his death is accepted with sadness and they unite in expressing deep sympathy to his widow, Louise.

Mike was born in Eureka, Calif., May 25, 1899. He received his early education at Eureka and entered Stanford University in 1918, obtaining A.B. and M.A. degrees in geology and mineralogy from that school. From 1922 to 1925 he worked as a mining geologist for Compania de Santa Gertrudis at Pachuca, Mexico, and then enrolled at Columbia University as lecturer in mineralogy. The following year he served as an instructor in field geology at Stanford University and then in late 1926 joined the Anaconda Geological Dept. at Salt Lake City where he was employed by Anaconda's subsidiary, International Smelting and Refining Co., as mining geologist.

It was during these early years working out of Salt Lake City at Tintic, Park City, Bingham, Mountain City, Nevada, and at other western mining districts that Mike won an enviable reputation as a hard working, talented geologist. His capacity to work rapidly and intelligently through a wide range of geological problems brought high recognition from his company associates and others who participated in the results of his excellent and constructive geologic studies.

In 1939, using the background of work he had done at Tintic, Utah, Mike returned to Stanford University to complete academic requirements for a doctor's degree and submitted for thesis his outstanding treatise on the geology of the Tintic district. He received the Ph.D. degree and served with distinction as professor of economic geology at Stanford and as chief of the Stanford Geological Survey.

Returning to Salt Lake City in 1942 as assistant chief geologist, International Smelting and Refining Co., he was made chief geologist in 1945, a position he held until his death. During this period he directed the successful development of the Anaconda Darwin and Shoshone mines in southeastern California and was directly responsible for working out the structural geology that lead to discovery of the bonanza lead silver oreshoot at Shoshone.

In addition to the faithful performance of regular duties, he served with distinction on national and sectional committees of AIME. He was a founder and officer of Utah Geological Society and a fellow and Rocky Mountain Sectional officer of the Geological Society of America. He received high scholastic and scientific honors as a member of Phi Beta Kappa and Sigma Xi and was an author of notable scientific papers, publications, and lectures.

As an active participant in community affairs and as a member of the Armed Forces in World War I, he served both his fellow man and his country. But perhaps his greatest accomplishment was the inspiration he gave to those who for many long years worked with him. He was first and always a gentleman in the finest sense of the word. Considerate and thoughtful of others, he gave unselfishly of his fine talents in helping younger geologists and assisting all of us who came to him constantly for help and advice. Many prospectors and mining men will remember him for his understanding and sympathetic consideration of their problems. The mining world produces many men of great heart and superlative talents and Mike will be remembered always as one of them.

Worthen Bradley

An Appreciation By
Granville S. Borden

"Peace of Mind," according to the late Joshua Liebman in his masterpiece which bears this title, is the finest and most desirable of all good attributes possessed by human beings—without this precious possession, fame, power, wealth, achievements are worthless.

Our God blessed Worthen (Member 1929) with a superabundance of this virtue. It radiated from his personality to all of his friends and acquaintances, engendering in them some of his goodness, kindness, and complacency, which in turn was rebroadcast to hosts of his fellow men.

The mining and military records of World War II prove beyond any reasonable doubt that the Bradley Mining Co., owned and operated by the lineal sons of the late esteemed and renowned Frederick W. Bradley, made stupendous contributions to victory of our beloved country through the discovery, development, and production of the famous tungsten deposit at Stibnite, Idaho, at a time when our success in World War II depended upon procuring an adequate domestic supply of this most critical and strategic mineral.

Worthen was for many years the president of the Bradley Mining Co.

Worthen was generically a miner, not only through endowments from his father, Fred Bradley, but also from the forebears of his mother, nee Mary Parks, famous miners in the Mother Lode Mining District of California.

Worthen started early to utilize his innate mining wisdom and make accretions thereto during vacation in the mines as a kid, through the University of California, and then in exploratory, development, and producing activities in mineral deposits carrying gold, silver, antimony, mercury, and tungsten, primarily in California and Idaho.

Worthen's endeavors were not confined solely to the mining fields, for he plowed, cultivated, and harvested in the less rugged fields of community endeavor, youth development, sports (primarily tennis), government, church, friends, and family.

Worthen left a splendid group to help complete his unfinished work—his lovely wife, Helen, his three sons—Clay, Ricky, and Stephen, his precious mother, his three brothers—Jim, Jack, and Sewall.

In this generation no one has contributed more than Worthen to the welfare and development of the San Francisco Section of AIME, the American Mining Congress, the Mining Committees of the State and San Francisco Chambers of Commerce, the Commonwealth Club of San Francisco.

Finally, on top of all of these achievements, Worthen was a grand

guy, a real pal, a devoted husband and father—loyal, honest, trustworthy, generous, kind; in brief—the epitome of goodness.

Messmore Kendall (Member 1915), lawyer, theatrical producer, and director of several copper companies, passed away on May 1, 1959. Born in Grand Rapids, Mich., he was educated at Columbia University, now George Washington University, and was admitted to the bar in Montana in 1894 and in New York in 1897. He has been director of Braden Copper Co., Andes Exploration Co., and president of Chile Bolivia Co.

J. Roy Vandenberg (Member 1957) was killed in an automobile accident Mar. 10, 1958, while coming from the oil shale mine, Rifle, Colo. He graduated from Colorado College in 1930 and worked for Public Service of Colorado until 1942. Successive jobs for the State Highway Dept. and the Eighth Area Engineers, Oak Ridge, Tenn., in their Grand Junction project, and with Independent Lumber Co. filled the years until 1951 when he joined Junction Bit & Tool Co. as sales and service manager.

Robert M. Haskell (Member 1940) died in Marquette, Mich. on June 5, 1959. He was born in Palmer, Mich. and was educated at Occidental College and the University of California, receiving a B.S. in mining. In 1911 he was working for Inspiration Consolidated Copper Co., surveying, and a year later for Ray Consolidated Copper Co., both in Arizona. He joined Cananea Consolidated Copper Co. in Mexico and in 1915 was flotation metallurgist and superintendent for Calumet & Hecla Consolidated Co. in Michigan.

Walter Hull Aldridge

An Appreciation by
E. C. Meagher

The death of Walter Hull Aldridge (Honorary Member 1890) in New York on Aug. 16, 1959, approximately three weeks before his ninety-second birthday, ended a career that on his retirement in 1957 had spanned 70 years in the mineral industry. It took from the ranks of our profession another of the old guard who by their brilliance and their courage opened up to commercial exploration so much of the mineral resources of the world.

Walter Aldridge was born in Brooklyn on Sept. 8, 1867, the third son and the sixth, and youngest, child of Volney and Harriet Hull Aldridge. After preliminary education at Brooklyn Polytechnical Inst., he entered Columbia School of Mines, from which he graduated in 1887, while not yet 20 years of age. His career at Columbia must have been interesting. A scholarship student, he lived at home, wending his way daily from Brooklyn Heights to the river, then by Fulton ferry to New York, thence by devious routes up to the college at 49th Street and Park Avenue. His studying was done mainly on the trolley or ferry because his class work and his active participation in interclass rowing, football, track, and baseball, in which he always took great pride, occupied most of the remaining hours of the day. How successfully he managed his time is evidenced by the high grades which subsequently resulted in his election to Tau Beta Pi.

Upon graduation from Columbia, he was employed by Anton Eilers as assayer and general assistant to Arthur Dwight at the Colorado Smelting Co. at Pueblo. It must have been a wonderful postgraduate course because after only five years, on the recommendation of Anton Eilers, he went to East Helena, Mont., as manager of the United Smelting Co. Thus at 25 years of age he was in charge of one of the largest smelting companies of its kind in the U.S. As a sideline he was made assistant treasurer of a power company then building the longest transmission line in the country, from the Ferry to Butte, and looked after the affairs of employes and stockholders of the Cokedale Coal

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and Coke Co. In a period of labor unrest, battles between financial giants and railroads, the solution of the problems that confronted him daily gave him a liberal education that was to pay handsome dividends throughout his life.

After five years in Montana he accepted Sir William Van Horne's invitation to take charge of all of the mining and metallurgical interests of the Canadian Pacific Railway. It was a challenge that appealed to young Aldridge, then 30 years of age, and the way he successfully met it is history. His negotiations with F. Augustus Heinze; construction of the Trail smelter; the perfection of the Anson G. Betts process for the electrolytic refining of lead; the purchase and development of the Sullivan mine; and the formation of The Consolidated Mining and Smelting Co. of Canada Ltd., are evidence of the validity of his firm conviction that engineering skill and scientific ingenuity will solve the most difficult of problems.

In 1911 he left Trail to join the Gunn-Thompson interests and to have an important part in the history of Inspiration Copper, Magma Copper, and The Mines Company of America, until 1916 when he became vice president of Texas Gulf Sulphur Co.

Early in 1918, Seeley W. Mudd having resigned to accept a commission in the U.S. Army, Mr. Aldridge was elected president of Texas Gulf Sulphur Co., a position he held until 1951, when he relinquished his duties as chief executive officer and became chairman of the board. Under his direction as president, the company built the plant and started its first operations at Gulf, Texas. Coming into production after the high war demand had ceased, and facing the competition of two well established producers, he looked for a new market. This he found in the fertilizer industry, which had always used pyrite as its source of sulphur. Thus in a short time the company was well established and rapidly took the position as leader in the industry. In 1957 he retired and was named chairman emeritus.

Throughout his life he received many honors. Columbia, his alma mater, awarded him the honorary degree of Sc.D. in 1929. In 1921 his fellow alumni elected him alumni trustee of the University for six years, and in 1929 the engineering alumni named him to receive the Egleston Medal. In 1953 he was awarded the Class of 1889 Prize Medal as a "Graduate who had distinguished himself in a sphere of human effort."

His fellows in the Institute, of which he had been a member for 70 years, on two occasions elected him director, and followed the award of the William Lawrence Saunders Medal in 1933 by electing him an Honorary Member in 1944. The John Fritz Medal was awarded to him by the members of the four national engineering societies in 1950.

He was a charter member of the Mining and Metallurgical Society of America, and had been a member for more than fifty years of the Institution of Mining Engineers, London; Canadian Institute of Mining and Metallurgy; and of the North of England Institute of Mining and Mechanical Engineers.

Walter Hull Aldridge bore all these honors with genuine modesty. Always self-effacing, he was as generous in sharing his honors and his resources with others as he was in advancing their interests. An incisive mind, which enabled him quickly to reach the core of the most complicated problem, together with his ability to single out the strong points of his subordinates, contributed largely to his own success and the success of his enterprises. An able engineer, a skilled manager, a resourceful industrialist, he was blessed with a delightful sense of humor, and will always be remembered by his friends and associates as a kind, considerate person, truly a gentleman.

Mr. Aldridge is survived by his wife, the former Maud Miller, two sons, Duncan M. and Walter V., and a daughter, Mrs. Katherine A. Zadra.

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Student Chapter, Faculty Sponsor, Local Section
or Prof. A. W. Schlechten
The University of Missouri,
School of Mines and Metallurgy,
Rolla, Mo.

James E. Gyde (Member 1953) was a student at the University of Idaho when he died in 1953. He had been born in Wallace, Idaho in 1934 and had gained mining experience working for a mineral surveyor and as geologist's helper for Bunker Hill at Kellogg, Idaho.

Clyde H. Shoemaker (Member 1937) passed away in 1958. He had been a consulting mining engineer in New York and vice president of Johns Manville Co. Born in Michigan, he received an E.M. from the Michigan College of Mining and Technology. He became acting department head of civil and mining engineering at Michigan College of Mines. In 1908 he joined Johns Manville Co. as mining engineer, mine and mill superintendent. He became vice president and general manager of Canadian mining and manufacturing operations in Montreal.

Alf Welhaven (Member 1907) died on May 20, 1959. He was born and educated in Norway, attending the Naval Academy of Norway from 1899 to 1901. He joined the Mariposa Comm. & Mining Co., gaining underground, milling, and office experience. Later he worked for Oriental Con. Mining Co. in Korea as superintendent. He became general manager of the firm and successively was general manager of Insular Lumber Co. in Manila, Big Wedge Mining Co. and Marsman & Co. Inc. in Baguio, P. I. He later came to the U. S. and was a consulting engineer in California and South Carolina.

Necrology

Date Elected	Name	Date of Death
1958	Louis Accorsi	July 5, 1959
1890	Walter H. Aldridge Honorary Member	Aug. 14, 1959
1925	Horace J. Allen	Aug. 15, 1959
1954	R. W. Baldwin	July 26, 1959
1922	C. T. Barker	June 8, 1959
1925	Richard L. Bowditch	July 31, 1959
1939	James McKean Bugbee	Unknown
1920	Blandford C. Burgess	Aug. 10, 1959
1957	Basil Dorn	Sept. 1958
1943	Harry G. Kennedy	Unknown
1925	Kellogg Krebs	Aug. 25, 1959
1946	Harold C. Lusk	Mar. 10, 1959
1925	Tom Lyon	July 31, 1959
1955	William J. Owen	August 1959
1913	W. E. Porter	Unknown
1913	Guy C. Riddell Senior Member	July 19, 1959
1914	G. B. Rosenblatt	July 15, 1959
1914	Arthur F. Taggart	Aug. 22, 1959
1903	William E. Wainwright Legion of Honor	May 3, 1959
1907	Frederic R. Weekes Legion of Honor	Sept. 2, 1959
1956	William Bourne Wood	Aug. 6, 1959
1936	Sergei E. Zelenkov	Aug. 16, 1959

Membership

Proposed for Membership
Society of Mining Engineers of AIME
Total AIME membership on Nov. 1, 1959, was 32,858; in addition 2,798 Student Members were enrolled.

ADMISSIONS COMMITTEE
A. E. Weissenborn, Chairman; Frank A. Ayer, Vice Chairman; R. T. Lassiter, Charles H. Lambur, Alfred D. Rood, William J. Rude, L. P. Warriner.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

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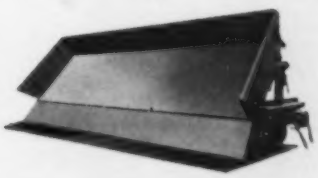

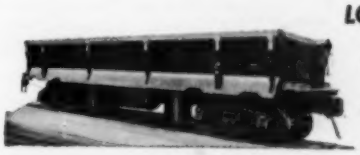

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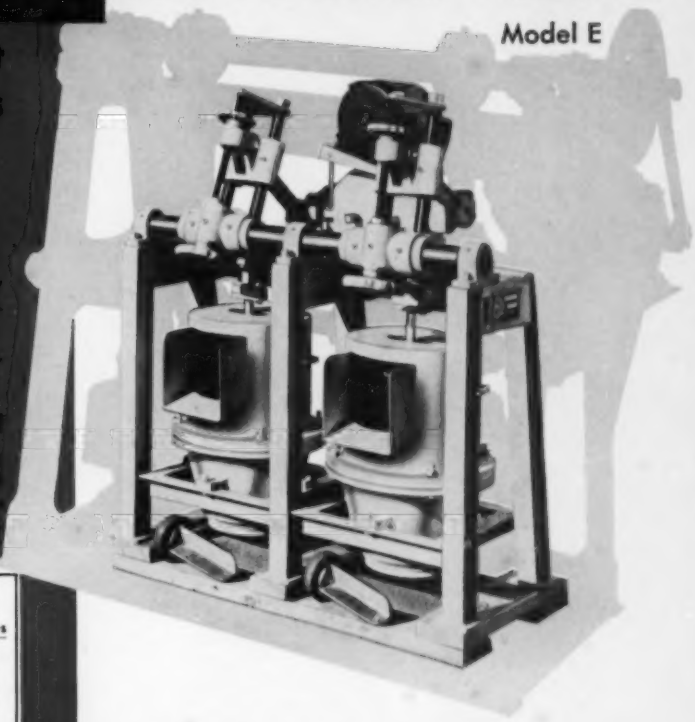
DENVER adjustable stroke DIAPHRAGM PUMPS

Model E



NOW...Smaller Pumps That Do As Much As Larger Pumps Used To Do!

For example:

3" DENVER Pump..... 45 GPM capacity
4" Other Pumps..... 45 GPM capacity

Now you get the capacity of the larger pump, plus line velocity engineered to keep solids from settling. Feed line velocity is uniform throughout the complete line of DENVER Pumps.

You save on initial cost—on maintenance. You get simple, compact design—rugged dependability.

Buy Your Pump by Capacity—Not Size!

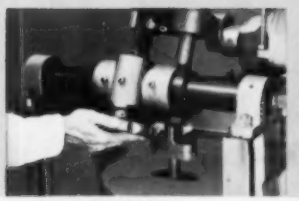
Table below shows new capacities of DENVER Pumps by size. Compare with the pumps you may now be using. Why pay more for a bigger pump when a smaller DENVER Pump will do as much? Determine the capacity required for your operation, then select the pump that does the job.

NEW DENVER ADJUSTABLE STROKE DIAPHRAGM PUMPS

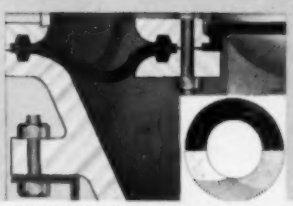
DENVER Pump Size	Capacity—GPM* SIMPLEX	DUPLEX	Line Velocity At Listed Capacities
2"	20	40	2.00 ft./sec.
3"	45	90	2.00 ft./sec.
4"	70	140	2.00 ft./sec.
5"	120	240	2.00 ft./sec.
6"	175	350	2.00 ft./sec.
8"	320	640	2.00 ft./sec.
10"	500	1000	2.00 ft./sec.

*at maximum stroke and normal speed. Stroke can be adjusted *while pump is operating.*

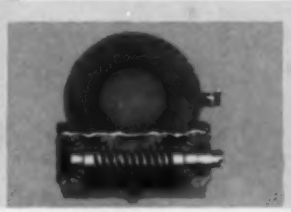
Sizes from 1" to 10", simplex and duplex, in capacities up to 1000 GPM —standard or acid-proof construction.



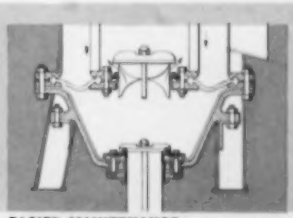
POSITIVE ADJUSTMENT and control are made while pump is operating by turning conveniently located handwheel. Improved design permits longer strokes, greater capacity.



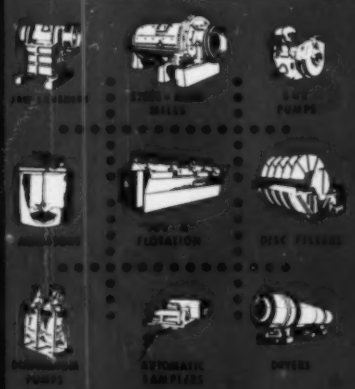
IMPROVED DIAPHRAGM is rubber, molded with patented spiral nylon cord construction to withstand constant flexing and permit longer stroke that boosts capacity up to 75%.



POWER ECONOMY results from anti-friction bearing design and simplified, efficient, running-in-oil drive. Reduces maintenance, assures long, trouble-free operation.



EASIER MAINTENANCE provided by simple design and such features as long wearing tough rubber valve seats that can be quickly and easily replaced.



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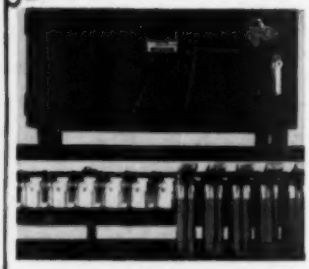
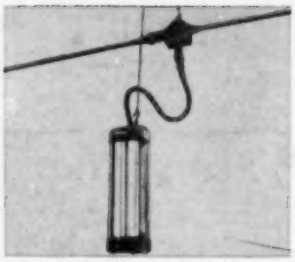
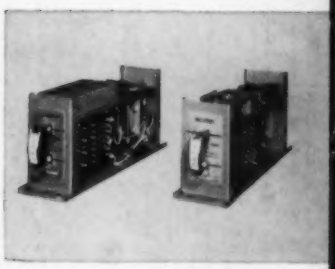
☐ **NEW EDISON MODEL S ELECTRIC CAP LAMP** provides greater safety for the miner, higher production for the operator. 15% increase in illumination. Smaller, lighter-weight headpiece. Improved battery.



☐ **M-S-A® AUTOMATIC LOW-VOLTAGE CHARGING SYSTEM** is designed for the most economical method of lamp charging. Miners can put their lamps on charge with one motion and keep moving without any delay.

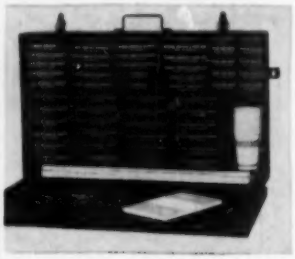


☐ **M-S-A® PERMISSIBLE MINE LIGHTING SYSTEM** cuts down accidents. Increases production. Provides dependable lighting with an instant start circuit. Available for either 110 or 220 volt AC circuits.



☐ **M-S-A® TRANSISTORIZED AUDIO TONE TRANSMISSION EQUIPMENT** permits economical centralized control and indication of fans, substations, motors, pumps, conveyor belts, switches, circuit breakers, and lights.

☐ **M-S-A® MINEPHONE** coordinates trip traffic for safe, fast, productive haulage control. Motormen have clear, instant voice communication with the dispatcher or other motormen while trips are moving. Installs easily.



☐ **M-S-A® MINER'S FIRST AID CABINET** provides medical dressings and equipment for mine hospital or dressing station. Each unit package individually wrapped in cellophane. When open, lid serves as a work shelf.

☐ **M-S-A® ALL-SERVICE® MASK** with new Window-Cator canister, external check valve and M-S-A Clear-tone Speaking Diaphragm gives dependable breathing protection against smoke, toxic gases and fumes.

☐ **M-S-A® CHEMOX® BREATHING APPARATUS** completely safeguards breathing while travelling through any gaseous or oxygen deficient area. Generates its own oxygen supply from replaceable canister.

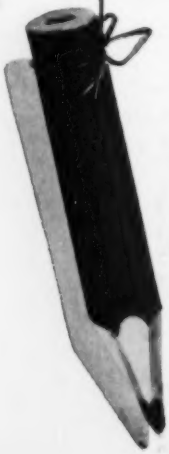
☐ **M-S-A® SELF-RESCUER®** gives immediate breathing protection in emergencies caused by fire or explosion. Compact. Lightweight. Can be stored without deterioration. Available in storage cases or individual carrying cases.

☐ **M-S-A® DUSTFOE RESPIRATOR** is light and compact for dependable protection against dusts, vapors, and mists. Allows maximum vision by the wearer. It's easy to clean. Design is modern and functional.

☐ **M-S-A® MINE RESCUE COMMUNICATION SYSTEM** with speaking diaphragm face piece sets up positive "party line" communication between rescue team and fresh air base. Transistorized. Battery-powered.

☐ **M-S-A® TYPE K SKULLGARD® HAT WITH NEW FIXED-CROWN* SUSPENSION** is safest on the outside, safest on the inside. New suspension provides an extra margin of safety which is completely tamper-proof.

*Trademark



☑ CHECK ITEMS OF INTEREST

We will furnish further details

Check off the MSA products which you would like to know more about. Then tear out this page, send it to MSA. We will send you the additional information requested. An MSA representative will be pleased to relate the advantages of these items to your operation: in terms of full-shift protection, more tons per man. No obligation, ever.

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